

Fluctuations in Housing Markets, Causes and Consequences

by

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Thesis

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The first time I became aware of the system dynamics (SD) method was about thirty years ago when I worked at the Norwegian Institute of Transport Economics. A colleague, Mr. Odd Gulbrandsen, used me as one of his “clients” when building a complete system dynamics model of the national transport supply and demand systems. After a dialogue he could leave my office, bringing with him a causal loop diagram (CLD) based on the things agreed upon during the discussion, then again, after a couple of hours, coming back and presenting DYNAMO equations and graphs based on the CLD! I became very fascinated, however, writing DYNAMO equations did not attract me much. On the other hand, CLDs have been useful for me since then for problem descriptions in the different jobs I have had.

Mr. Gulbrandsen eagerly promoted the method, and he and another colleague, Mr. Carsten Tank-Nielsen, arranged a “lynx-and-hares” model SD course for the introduction of the method to the interested non-SD colleagues at the institute. I remember that programming and running the model was a cumbersome affair. Since then I have recognised that graphically based software and personal computers have made the method much more accessible.

My former job was at the Norwegian Post and Telecommunications Authority (NPT). The currently named Ministry of Labour and Social Inclusion decided to move a number of governmental institutions from the capital city to the regions. NPT was among these institutions. We had three alternatives – quit, move with the NPT, or quit with an agreement of three years of studies with financial support. Very few jobs were vacant, and there was a deadline for the study alternative. Time was overdue when I finally decided to study - again. I am grateful that the NPT gave me the chance.

I am economist, and at first I had no intention of studying again. A colleague proposed studying law to me, but my patience for such a subject would probably be a problem. Other alternatives were considered. After thinking about what I really wanted to study if I had the opportunity, my thoughts spooled back thirty years to my SD colleagues’ inspiring work - system dynamics would be great! I am thankful to my former colleagues for their inspiration.

Meanwhile, when I made up my mind, I realised that I could study SD at the University of Bergen (UiB). I called Professor Pål Davidsen at the SD group and told him about my situation, and he eagerly encouraged me to take a course. I was still a little hesitant, but Pål Davidsen moved my position closer to decide upon studying – thanks to him for that! During the autumn 2005 I had the pleasure to follow lectures and to be advised and inspired by Pål Davidsen, Erling Moxnes and David Wheat.

After the autumn 2005 I returned to Oslo and kept on studying mostly as part-time student. Professor Erling Moxnes has supervised my thesis project. I am very grateful to him for his patient attempts to help me understand the many intricate SD principles, either when I went to Bergen in order to confer with him, or on telephone.

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ABSTRACT

New housing construction represents a relatively small fraction compared to the total mass of housing. Therefore, the supply of housing in the short run is fixed. For this reason relatively small changes in demand for housing will affect prices considerably. If housing prices exceed construction costs, new housing construction will take place. The price-cost relation is important for decision makers in order to start construction of new housing. The number of housing projects in the supply line is not well known and perhaps not taken into consideration by those who decide whether to start new housing projects or not. For this reason, and the fact that it takes considerable time to complete housing projects, there is a potential for fluctuations in the supply of new housing. Consistent with this hypothesis, the housing market fluctuates considerably more than any other principal activity in the economy.

Since the supply of new housing fluctuates, employment also fluctuates. Developing efficient worker teams takes time, and recruitment of workers and apprentices occurs when the industry is in expansion. When activity in housing construction is low, recruitment is low, which in turn will imply shortages of skilled labour when the market expands again. Craftsmanship and cost of new housing will also be affected by the quality and efficiency of labour.

Fluctuations represent a welfare problem both for the general public and for those who are working in the construction industry. Fluctuations represent unintentional losses or unexpected profits for house owners who are moving from one home to another as requirements change. Since fluctuations in the housing market are unforeseeable to the general public, there is also a loss of welfare for those who lose money in transactions in the housing market, for instance when buying a home when market prices are at the top and selling the old home when prices decrease. Much of people's assets are tied up in residential properties – in Norway some 80 percent of the households “own” their homes, more or less based on loans.

More than in other economic sectors, employees in the building and construction sector are affected by fluctuations. Those who are recruited to the housing construction industry are at a risk of being jobless. On the other hand, when construction activity increases after a depression, the activity increases to unfavourable levels with stress, overtime and rework for those involved. Architects, planners, estate agents and construction workers are all heavily affected by fluctuations in the housing market.

1 INTRODUCTION

The total supply of housing depends on new housing construction rate, reconstruction, change of use, vacancies, demolition and destruction. Buildings' lifetime is very long, which implies that the annual housing construction rate is small compared to the existing mass of homes – either measured by the number of housing units, or housing area. Changes in the population, income, tastes and personal requirements imply redistribution of the existing stock of homes by means of the market for housing – selling the object you do not need and purchasing another object that better suits your current needs. Real estate developers are in business in order to earn money. Therefore, when prices for housing are high relative to the costs of construction, construction of new housing will take place, increasingly more the higher the profitability, provided that capacity allows. On the other hand, when prices are lower than costs, new housing construction will decline. For this reason, price fluctuations in the housing market have considerable effects on the incentives for building new housing. In economically prosperous periods, over-establishments have occurred because there are no mechanisms in the industry itself to control how much there is in the supply line, and to adjust capacity accordingly. The time from a decision to start housing projects to completion is usually long. For this reason housing completions planned when profit margins were good will still take place for some time also when profitability turns down.

Hence, the housing construction industry's related labour market is also heavily affected by fluctuations in housing prices. Housing construction has fluctuated much more than activity in any other principal industry, and, compared to any other principal investment activity, investment in housing has fluctuated considerably more. Consequently, recruitment to the industry has fluctuated. One informant for the current modelling maintained that it takes three to five years to establish an efficient worker team in housing construction. For this

reason, fluctuations will also imply fluctuations in the work quality as well as in efficiency. There is no mechanism to ensure stability in the recruitment of skilled labour. Additionally, fluctuations will cause loss of welfare in the downturns for those employed in the construction industry.

There is not too much of publicly available system dynamics approaches to analyse the housing market and housing construction capacity simultaneously. There are no publicly available system dynamics approaches – as far as the following literature review indicates - regarding attempts to manage housing supply line and the corresponding provision of planning and construction capacity.

On the other hand, it seems to be a relatively large amount of economists' approaches to questions regarding demand and supply of housing, usually by means of traditional economic theory and econometrics.

The aim of the current thesis is to describe the housing market, housing construction, supply, demand and the housing construction labour market in order to reveal essential mechanisms, and to propose policies to achieve better functioning both in the housing supply as well as in the labour market related to housing construction. Research methods include literature reviews and retrieval of other information, interviews with key persons in the industry, research and consultancy, statistics and system dynamic modelling.

Chapter 2, 3 and 4 give a historical introduction to the housing market development in a Norwegian context, a problem statement, and a hypothesis that the housing market system is unstable and causes cycles.

Chapter 5 includes a review over relevant literature, including both system dynamics approaches and other dynamic considerations, as well as more traditional econometric approaches.

In chapter 6 the system dynamics method is briefly explained and related to the described problem of cyclical behaviour in housing construction, supply, demand and capacity. Chapter 7 gives a detailed formulation of the model, both the base model as well as the extensions used in following chapters. The results of a base run are presented.

Chapter 8 deals with model sensitivity testing. Inclusion and exclusion of model structure, reproduction of historical development and numerical sensitivity are among the tests performed. Partly as a result of the testing, policy parameters and structures are identified and discussed in chapter 9 in terms of feasibility as instruments for housing market system improvements.

Summary and conclusions from the current work are presented in chapter 10. During the modelling process, new ideas of how to enhance the model have emerged, and these are presented in chapter 11.

2 A BRIEF OUTLINE OF HOUSING HISTORY IN NORWAY

2.1 FROM AGRICULTURE TO INDUSTRY

At the end of the 19th century the industrialisation and migration to the cities from the countryside resulted in huge housing problems - lack of housing, overcrowding and consequently health problems. Some larger industrial companies built homes for their employees. The intention for doing this was probably based on the employers' need for a stock of healthy and efficient workers, and to attract workers more than for welfare as such.

At the end of the 19th century, a lot of blocks of flats for tenants were built, first and foremost in Oslo (formerly Kristiania), but also in other increasingly densely populated areas. This initiative was based on profitability due to the in-migration from the countryside of people who wanted jobs in the new industries. In 1899 the boom halted, in particular in Kristiania, caused by an economic downturn. This was called Kristianiakrakket (the "Kristiania bust"), and after a few years, ten per cent of dwellings in the blocks of flats in Kristiania were vacant. Speculation, not social housing construction, was the basic reason for Kristianiakrakket. In general, these homes had a poor standard. The speculation was supported by all the new and more active banking institutions established in the 1890-ies. The older financial institutions were more cautious and reserved; their experienced management remembered the losses caused by the real estate speculations preceding a minor crack in the 1870s (SSB (2001)). Kristianiakrakket caused construction of blocks of flats for tenants to

cease, more or less, until the 1930s. During the first years of the 20th century, the municipal authorities in the cities engaged themselves in building blocks of flats for hire, and the first housing co-operatives were established around 1930. The aim of the co-operatives was to construct healthy homes of good standards for people with limited means. Trade unions were important proponents for these initiatives.

2.2 POST-WAR DEVELOPMENTS

Housing construction halted more or less during the Second World War. After the war housing was insufficient, characterised as “housing famine”. Some people did not have a home, and many lived in small houses and with lower housing standards than justifiable (TOBB (2008))¹.

The Norwegian State Housing Bank (NSHB) was established March 1 1946 in order to compensate for weak financial institutions, and, as an instrument for implementing public housing policy. This institution has played a central role in the Norwegian housing policy, and so far 2/3 of the housing stock has been financed by the NSHB. NSHB has contributed to stability and predictability in housing construction (Haga (2006)). From being an instrument for a general housing policy, NSHB current activities are for homeless and economically disadvantaged people, and for those who are going to establish themselves for the first time in the housing market.

From 1980 private financial institutions have gradually increased in importance and influence in the housing market. According to a general liberalisation trend, regulations in the housing market have been removed, such as price regulation of parts of the housing stock and permission to split up housing co-operatives. Additionally, the politicians and the National Bank abandoned the so-called “low interest rate policy” in favour of stable prices nationally as well as foreign exchange rates, in which the sight deposit rate is an important tool. This has also had a major impact on financial institutions’ interest rates.

¹ TOBB is a housing co-operative in Trondheim

The post-war housing policy has been to let people establish themselves in owner-occupied homes. About 80 per cent of the households own their homes. This is considerably more than in other comparable European communities. The aim of the NSHB was to promote people to build small housing for themselves – loans were admitted for new housing construction, preferably based on personal efforts in addition to professional assistance.

The “self-builders” are rare today. Real estate developers are increasingly doing the job of planning and construction. The NSHB has also changed from solely to grant loans to new housing. NSHB now also grant establishment loans to people who buy homes in the existing housing stock.

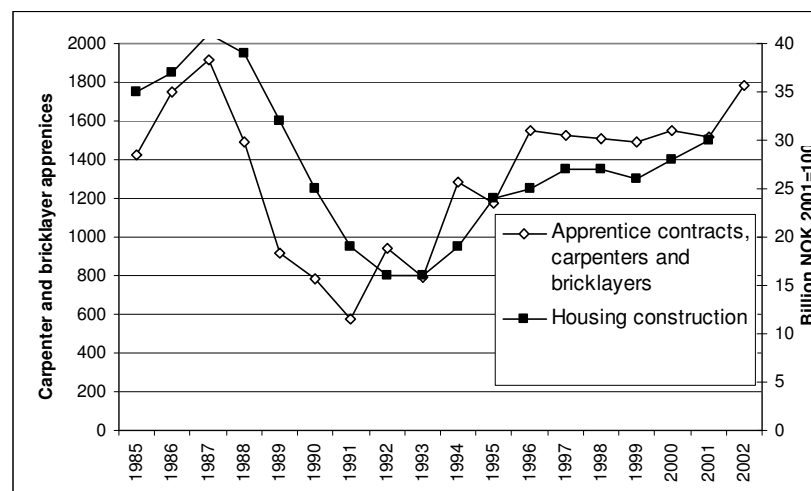
3 PROBLEM

From a situation when parts of the housing market were strictly regulated, the existing mass of homes has, by and large, recently been distributed among people by means of some sort of market mechanisms. When peoples’ needs with respect to housing is changing, the market is currently also the tool for redistributing homes according to the ability and willingness to pay, tastes and requirements. Existing homes are sold, usually in order for the seller to buy another home. In some cases, older housing buildings require reconstruction, such as splitting up or merging units in order to meet changing needs. New housing construction will meet the additional demand caused by growth in population and income, and, new housing will usually adapt closely to buyers’ current requirements. Real estate developers’ anticipation of trends and tastes adjusts the supply of different types of housing over time. One example is the current tendency to construct blocks of flats with rather small dwellings. The demand for such housing has been high, reflected in the high prices related to the rest of the housing market. Developers seem to adjust by increasing the activity in partial markets in which prices, or profit margins are relatively high. Recently there has been a considerable increase in construction of blocks of flats with smaller units. A reason for this is probably that the price level for small apartments has increased considerably more than for instance for detached houses. The profitability of building blocks of flats has therefore increased, and consequently construction of this kind of homes has increased.

Buildings' lifetime is relatively long compared to other consumer assets, such as cars, washing machines etc. For this reason, construction represents a relatively small fraction of the total housing stock either measured by the number of units or the square meters. Therefore, relatively small changes in the demand for housing may cause considerable changes in prices, and therefore also in housing construction. The relation between market price and cost of new housing is critical to whether investments in new housing will take place.

Fluctuations, particularly in the housing construction labour market, affect costs and quality in construction as well as welfare for those who educate for a career in this industry, and those “unskilled” who are practicing to gain skills, enabling them to work efficiently in the housing construction industry. One informant, who had a long-lasting occupation as carpenter before he turned over to an academic career, dealing with issues in the building and construction industry, indicated that “it takes 3-5 years to build efficient work teams in the housing construction industry”. Another informant, a labour union representative, maintained that “parents clearly recommend their children to avoid vocational education when the situation in the industry is bad - recruitment takes place in good times”. Additionally, employers will be reluctant to give contracts to apprentices in downturns. Figure 1 indicates a relationship between activity in housing construction and the number of apprentice contracts. The number of apprentice contracts seems to vary closely according to housing construction.

Figure 1: Carpenter and bricklayer apprentice contracts (number of contracts) and housing construction in billion NOK 2001 values. (Sources: Norw. Ministry of Education and Research, and Statistics Norway)



When housing market prices decline to a lower level than the costs of building new housing, the activity in the housing construction industry slows down or halts. On the other hand, when housing market prices are high compared to current construction costs, the existing construction capacity will be fully employed in order to gain profits, and capacity will be expanded. Established players in the industry may have different strategies, some will increase the capacity in order to gain higher profits, while other players may keep the existing capacity within reasonable limits and reject projects exceeding their current capacity constraint. It has been considered easy to start construction businesses in the housing construction industry. This, and a recent tendency to recruit unskilled labour and skilled workers from foreign countries, will add capacity to the industry, at least for the construction of small houses, i.e., detached houses, which probably are the easier projects to cope with compared to constructing large, multi-household buildings.

Figure 2: Real price indices for home units in different types of buildings (deflated by the consumer price index). (Source: Statistics Norway)

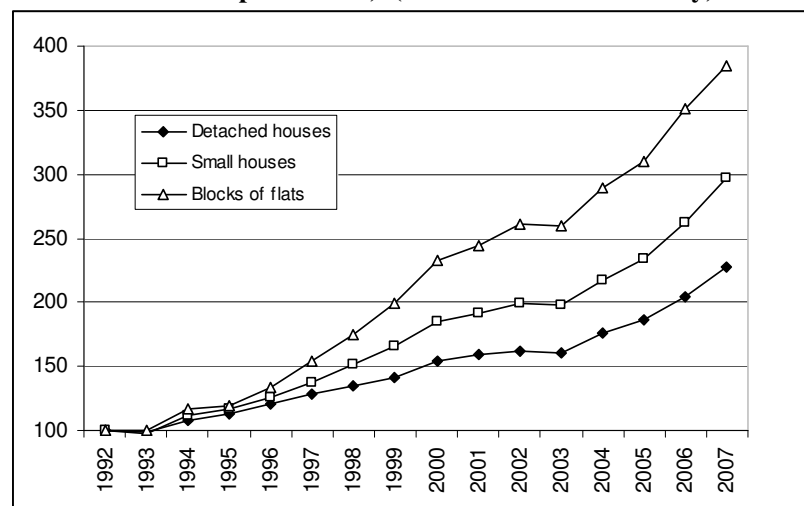


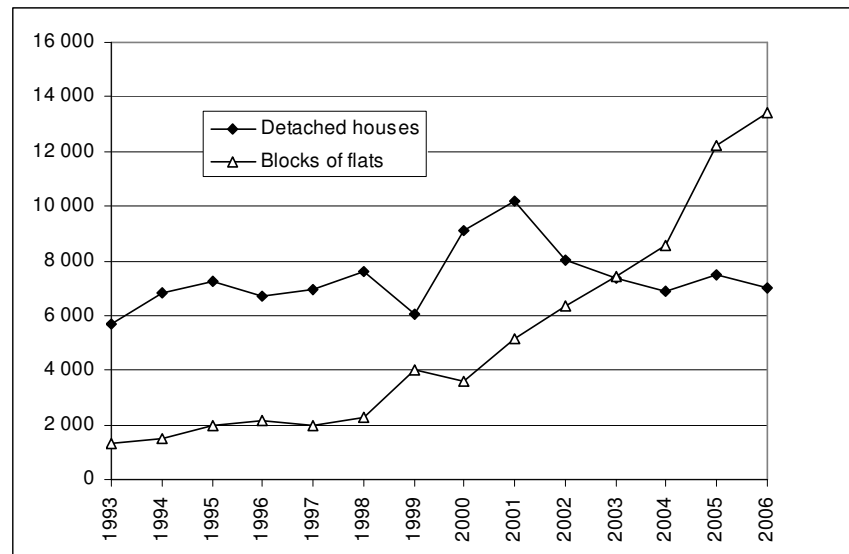
Figure 2 exhibits the development of real prices of housing units in different building categories – detached houses, small houses and blocks of flats². The figure reflects that the demand relative to supply for housing units in blocks is greater for dwellings in blocks

² Small houses include housing with more than one dwelling; i.e. semi-detached houses, row houses, terraced houses and other small houses. Blocks of flats include “flat blocks and apartment houses with three or more stories” (Statistics Norway;

compared to small and detached houses. For this reason the price increase has been greater for such housing compared to the other two categories. A similar difference between the price curves for small houses compared to detached houses reflects a relative scarcity of dwellings in small houses compared to detached houses. The curves hide the fact that multi-household dwellings are more typical for the cities than for the regions. Even if we control for that, the *pattern* is the same for instance for the larger cities, however, the discrepancy between the three categories of housing is somewhat less than indicated in Figure 2.

Construction starts are represented in Figure 3. In recent years the number of construction starts for blocks of flats has increased considerably compared to detached houses (small houses has been left out). In 1993 the number of new units in blocks was at a level of less than 2000. In 2006 the construction starts were close to 14,000 units, or more than seven the level in 2000. This is perhaps an indication that construction is driven by the significant development in prices, and thus also profitability for this category of housing compared to detached houses. In total, construction of detached houses has declined or stabilised in recent years after a peak in 2001.

Figure 3: Construction starts, housing units, for detached houses, small houses and units in blocks of flats 1993-2006. (Source: Statistics Norway)



High profitability and consequently the build-up of capacity will attract people to work in the industry at increasing wage rates as the scarcity of skilled workers increases. Because of the ease of starting new construction businesses, and the time lags, there are no

mechanisms, or at best weak mechanisms, to prevent the build-up of excess capacity when prices are stabilising or declining again. Prices are stabilising when supply meets demand, and prices tend to decrease when supply of housing exceeds the demand. The large players in the industry have no means for supply chain control in order to regulate the total supply. For this reason, some of the larger players are trying to control and reduce unit and area cost through efficiency improvements. When supply after some time exceeds demand, the new and usually small establishments exit from the market and the larger players keep or scale down capacity, especially by dismissing or firing workers in order to adjust new housing construction in accordance with the reduced demand.

These supply chain mechanisms consequently have huge effects on employment. For this reason employment in the building and construction industry (BCI) fluctuates very much, and considerably more than in most other economic sectors. Employment fell from approx. 47,000 to 15,000 workers from 1987 to 1993, or 67 percent, compared to a 4.6 percent general reduction in employment in the same period. The building and construction industry i.e., housing *and* other construction) represents 8-9 percent of total employment in Norway, and 4-7 percent of total gross product in the economy as a whole (Andersen 2004). Architects were heavily affected by the construction industry downturn 1987-1992. Compared to the total average unemployment which peaked in 1992-1993 at 6 percent, the unemployment for architects was at a level of 8.2 percent. However, this is perhaps not necessarily the most relevant measure – under-utilisation, a measure combining unemployment and under-employment was estimated to a capacity under-utilisation at about 27 per cent (Lykkeutvalget (2002)). In addition there is a supplier industry representing materials, machine rental, transportation etc., which, to the extent directly involved in building and construction, is affected by fluctuations in building and construction. In particular, housing construction fluctuates more than the rest of the building and construction sector, which also includes construction of airports, roads, public and private factories and office buildings etc. The maintenance and reconstruction activities combined with construction other than housing construction have a subduing effect, though these activities still fluctuate more than investments in most other sectors and more than the economy as a whole.

From the end of the Second World War up to 1980 fluctuations in the Norwegian housing construction industry were moderate. Possible explanations are public regulations, credit and material rationing, and strict regulation of the interest rate level for housing

investments. As previously explained, The Norwegian State Housing Bank was the major player in financing housing.

Summarised, the emphasis has changed from a highly regulated approach to less regulation, from central decisions to de-central decisions, from price regulations to free price formation, from strictly regulated housing construction standards to more lively architectural approaches.

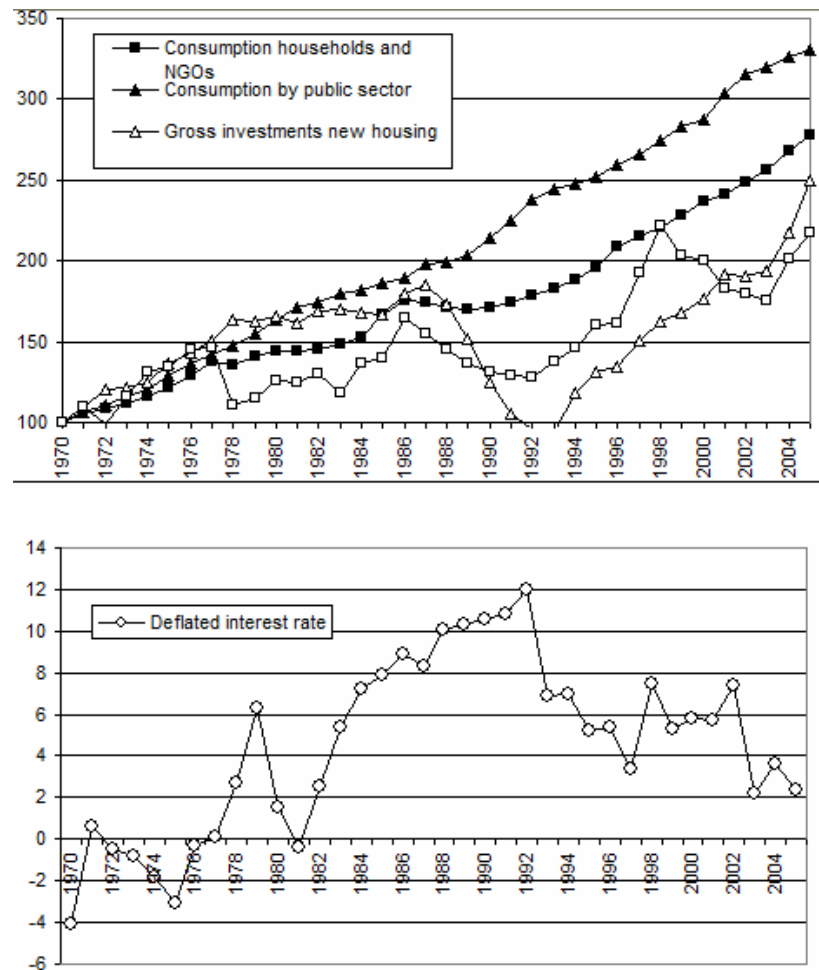
4 A DYNAMIC HYPOTHESIS

The period 1950-1980 was more of a regulated community with a subsequent co-ordinated chain of decisions, and obviously “paternalism” in the judgement of peoples’ needs regarding housing standards. The Norwegian State Housing Bank, financing most of the housing stock, had clear rules that to a high extent limited desires regarding comfort and space in new housing stock. The “low interest rate policy”, originally supposed to be beneficial for the income levelling, represented a stabilising element in the house owners’ housing costs. The potential drawbacks of these policies were welfare losses because people could not always choose housing according to their preferred standards, given their willingness and ability to pay, waiting time for getting loans, queues for housing in the co-operative housing system etc.

The liberalisation after the early 1980s gave more opportunities for people to choose themselves – housing standard, financing, when to buy and where to live etc. On the other hand, uncertainties arose regarding increasingly fluctuating interest rates and the timing for selling and purchasing homes in a market with amplified price fluctuations. After the housing market downturn that started in 1987/88 there were numerous examples that people who invested in a new home, and tried to sell the house they were leaving at a highest possible price lagged behind the rapid decline in housing market prices. When they finally were forced to sell in order to raise money for their new homes, some of them had lost as much as 30-40 percent of the value of their sales objects over 1-2 years.

Figure 4 indicates fluctuations in consumption, new housing investments, other gross investments and interest rates.

Figure 4: Consumption, investments, volume indexes 1970=100, and real interest rate in per cent (nominal interest rate corrected for inflation). (Source: Statistics Norway)



Fluctuations exist in public sectors' consumption as well as private consumption, depending on the general activity level. However, in general, investments fluctuate more than consumption, and housing investments fluctuate even more. As indicated in the figure, the interest rate *seems* to have an effect. The interest rate was low and there was a steady growth in housing investments from 1970 to 1982/1983. After that, interest rates increased considerably, and new housing investments declined from 1987 to 1992 to a level lower than in 1970. When interest rates declined again after 1992, the housing demand and construction rate increased³. Economists often point out that interest rates and employment have significant effects on the housing market. After a long period of *increasing* housing prices, economists are explaining this phenomenon by the so-called “fundamentals” - housing prices

³ This will be analysed in the chapter Model testing and validation

related to income or rents, the level of unemployment, interest rates and construction. Cycles are hardly mentioned.

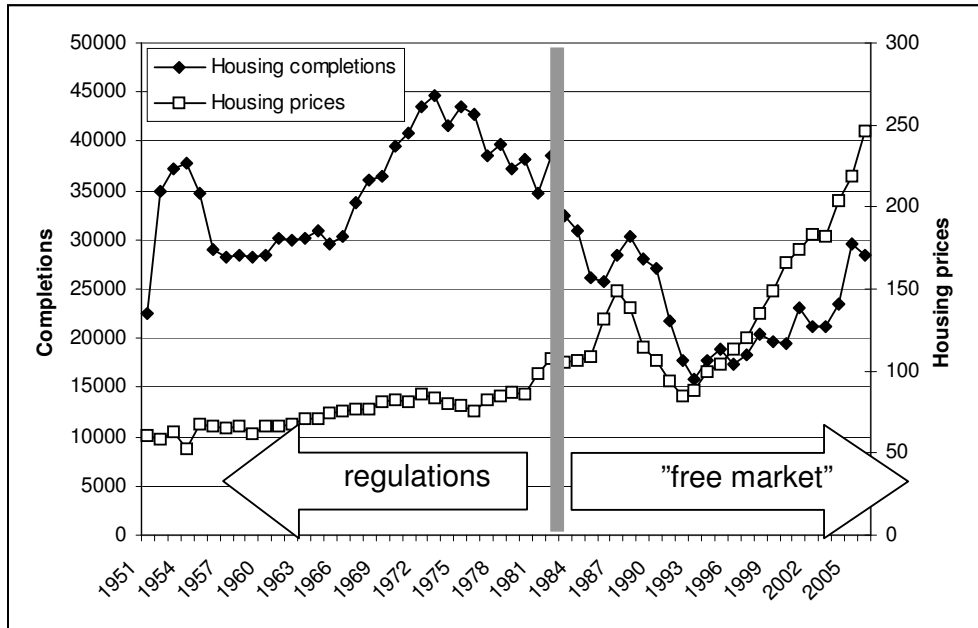
Cyclical behaviour of a system may arise when balancing loops with considerable delays are in effect. One significant balancing loop is the “profitability-supply loop”. As prices declined from 1987/88 to 1992, incentives to build new housing shrunk. However, the decline in the number of completions did not appear immediately; completions declined gradually from a level of 30,000 units in 1987 nearly to the half in 1993 - to 16,000 units. The reason for this was that housing under construction was completed. The drastic “undershooting” reduction in supply implied that the demand/supply ratio increased, among other things because of the growth in the number of households. Since 1993 the prices have increased much, as well as the construction rate. Now in 2008 a correction seems to take place.

Another important loop is the “demand-price loop”. The isolated effect of the price decline increased desired housing and gradually also the demand. This, in turn causes price to increase.

The downturn after 1987/88 deteriorated the construction capacity. For a long time after 1993 the industry has been troubled by capacity constraints, partly caused by the downturn from 1988 to 1993. Building capacity takes time, and much of the price and cost increases since 1993 may also have been caused by a delayed build-up of construction capacity.

The reference mode is illustrated in Figure 5. The figure indicates that there is one period of a regulations regime before the early 1980s, among other things with a relative shortage of housing, price regulations, credit regulations and one large actor that financed new housing – The Norwegian State Housing Bank. The “free market” period grew up during the 1980s. The private financial institutions more or less took over the financing of housing construction, and many of the regulations were removed. The “free market regime” is indicated to the right in Figure 5, in which we may observe a new tendency after the regulations regime – a cyclical system.

Figure 5: The reference behaviour: Housing completions (units) and housing prices in four cities in Norway. (Sources: Norges Bank and Statistics Norway)



Even for a constant population and a constant income per capita the described balancing loops may cause cycles. The housing stock is depleted by removals and the demand-supply relationship will change. This will, in turn, result in price increases when demand for housing exceeds the existing housing stock. Consequently there will be incentives to construct new housing that adds to the total stock again, resulting that total housing supply increases. Because of delays in the system, oversupply will occur, resulting in price decreases again.

The dynamic hypothesis does not imply that factors such as interest rates and unemployment are unimportant. As indicated, a dynamic hypothesis includes the question whether the system itself may cause fluctuations if the system is disturbed, for instance either by changes in interest rates, in the economy, employment, or other factors.

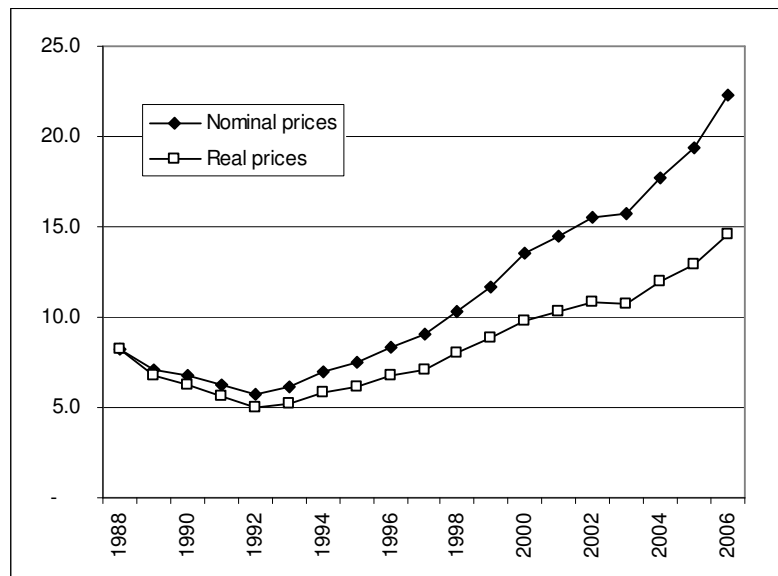
5 LITERATURE REVIEW

5.1 CURRENT DISCUSSIONS

After the downturn in the Norwegian housing market in 1988, it took eight years before *nominal* housing prices passed the 1988 level, and ten years before *real* housing prices again

exceeded the 1988 level (i.e. average housing prices at national level deflated with the consumer price index). Real prices in the Norwegian housing market have, in general, increased from the bottom year 1992 to 2007. Figure 6 indicates price development since 1988.

Figure 6: Nominal and real prices (1988=100) for housing, average for Norway. (Source: NEF, Norsk eiendomsmeklerforbund⁴)



The current news about housing prices are “congested” with a variety of experts’ opinions whether the housing prices still are going to increase, or decrease. Other spokesmen argue for stabilisation – “soft landing” - because the general national economy currently and probably for years to come is, and will be, in a very good condition. Various expert opinions regarding housing prices seem to be based on accentuation of particular influences, not a complete evaluation.

Andrew Ford, Professor of Environmental Science at the Washington State University, USA, has the following reflection about real estate spokesmen: “Most authors talk about everything in the market except the real estate cycle. Their books are filled with chapters on locations, incomes, general businesses, and mortgage rates. The real estate cycle, on the other hand, is missing from the Table of Contents and even from the Index.....Our brief review has

⁴ <http://www.nef.no>

found only three books that devote serious attention to the cycle....”⁵. Ford’s arguments refer to the situation in USA for “hardback literature” and other serious sources in the field of real estate market research, but his statement for USA seem to prevail for the discussion in Norway as well – arguments that prices shall go up or down, or that “soft landing” will occur, not cycles. However, there are sources not based on system dynamics approaches, for instance based on for instance cointegration methods in econometrics that have dealt with housing investments as a dynamic element linked to the profitability of constructing houses.

5.2 SYSTEM DYNAMICS BASED APPROACHES

It seems to be relatively few system dynamic approaches to analyse the market for housing in depth, and a very few about cyclical behaviour. Seemingly, system dynamics approaches take capacity limitations in housing construction into consideration. The following papers include related aspects from the housing construction industry:

Hong-Minh (2000) presents a system dynamics approach to the production process in housing construction in the UK market, estimating the effects of construction work in progress and average construction lead times. The model represents a first phase in the development of a total housing construction model, and this partial model describes the supply chain closely. The aim of this work is to reveal differences and similarities with other manufacturing processes, and to search for better methods of housing construction, which, in the UK, is regarded to have poor efficiency compared to most other industries.

Chen (2005) has analysed the so-called housing market price “bubble” in the Shanghai real estate market especially with respect to a hypothesis that speculation boost price levels. His findings are that the general demand for housing is a main driver for housing prices, but the author also concludes that speculation may boost prices. Also the fact that Shanghai is an increasingly internationally oriented region tends to boost prices. The number of house owners with “overseas passports” is growing rapidly - “According to the statistic, in 2003, 40 to 50 per cent of the buyers of new homes in Shanghai were people holding overseas passports, as compared to around 25 per cent in 2002.” The work does not include aspects on

⁵ <http://www.wsu.edu/~forda/ohome.html> (as of November 24 2007)

the possible cyclical nature of the housing market. Chen (2005) analyses the boom in housing construction, not cycles.

Kummerow (1999) has analysed cyclical office oversupply in, according to himself, a simple model with a system dynamics approach. He maintains that “Model lag and adjustment parameters similar to real office markets generate explosive cycles”. Further he says: “Uncoordinated management, poor communication, lack of information and naïve decision policies lead to unsatisfactory outcomes”. By improving the information structure, he maintains that cycles will be reduced, and, “at the market or national level, reducing risks requires collective choice and institutional innovations”.

Sterman (2000) represents perhaps the “state of the art” textbook in the field of system dynamics for business. This source includes a chapter on “boom and bust in real estate markets” in which a model draft for real estate markets is represented. This model includes a “speculations” loop, which certainly may exist for non-residential construction, i.e., in the commercial real estate market, probably also for housing. Sterman refers to an approach at MIT, in which students interviewed real estate developers. A main finding in the referred study was that developers did not pay much attention to what is in the pipeline, i.e., how many units or square meters of housing that already is under planning and construction. Interviewees focused on current profitability and location, despite the fact that construction is observable, and the number of permits may be checked before a new housing construction project is implemented.

5.3 OTHER DYNAMIC APPROACHES

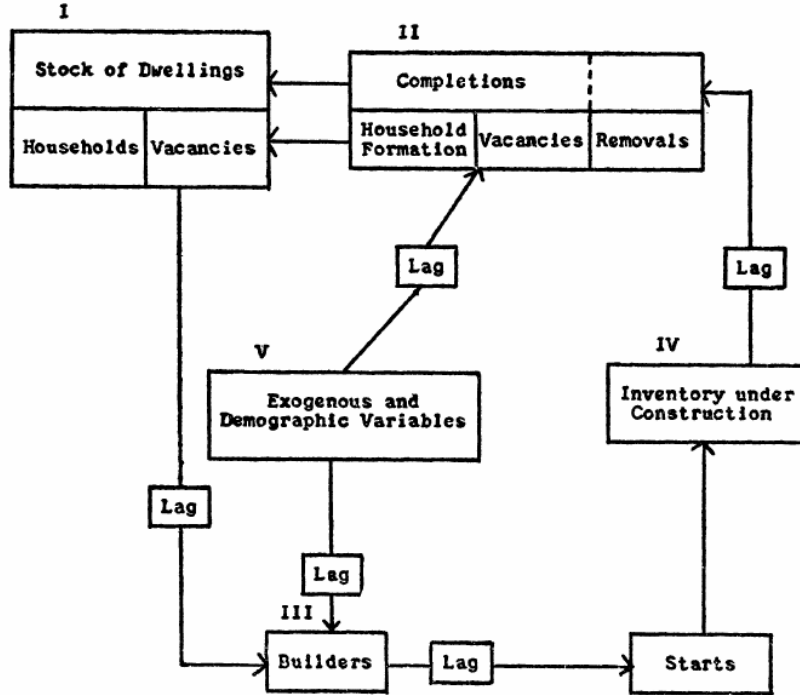
Maisel (1963) has presented a theoretical framework for modelling housing markets. His theoretical model is based on feedback with lags. Endogenous variables include *builders* (for instance as a starting point), construction starts, inventory under construction, completions, stock of dwellings which feeds into household occupancies and vacancies, then ultimately ending up at *builders* again. Exogenous variables are income, credit, relative prices, and additionally demographic factors. Figure 7 illustrates the theoretical framework Maisel (1963) has used in order to statistically test four equations derived from this figure (simplified in this presentation):

```

net_household_formation = f(population,income,unemployment,credit,prices)
removals = f(governmental_action,income, vacancies, housing_stock)
change_in_vacancies = f(costs,expectations,credit,rents,prices,vacancy_disequilibrium)
changes_in_housing_under_construction = f(starts,completions)

```

Figure 7: Structure of the housing market according to Maisel (1963).



Maisel writes: “Now assume a shift in exogenous variables..... Such shifts either may affect builders directly or may change the rate of household formation and removals. Changes in the stock become known to builders through data on vacancies, prices, rents and rapidity of turnover. If the information is favourable, builders raise starts, enlarging the inventory under construction and eventually, boosting the rate of completions. Unless by chance demand raises at the same rate as completions, vacancies will increase. As this fact also filters through to the builder, he will contract his starts..... The lag between starts and completions may also lead to an inventory cycle.” Maisel refers to spokesmen who argue that “vacancies for sale are found... Again owners attempt to keep these at a minimum. Most vacancies result primarily from emergencies, death, foreclosures or migration. Real estate men advise against vacating a unit prior to its sale because an owner’s expenses continue for the empty unit, placing him at a disadvantage”. Maisel himself maintains that in addition to inventories under

construction, vacancies are important in analyses of cycles. Maisel (1963) has statistically tested his model with respect to observed values, and the model estimations for certain variables fit well to historical data. He found that 85 per cent of the variance in construction starts was caused by vacant housing, demand less than 15 per cent of the variance.

DiPasquale and Wheaton (1996) employ a stock-flow model to describe the housing market – this is a frequently quoted source. In their approach they assume “that house prices in any period are determined only by current values of the model’s other variables, while the stock of housing depends on the historic values of these variables”. Their model’s behaviour is presented with various preconditions regarding price expectations – 1) exogenous expectations, 2) myopic backward-looking (or adaptive) expectations, and 3) rational expectations. 1) is based on beliefs that prices grow with the general economy. 2) is based on the households’ belief that past trends in housing prices will sustain (by adaptive expectations people establish their expectations about future on observations of the past). 3) implies that the households and/or producers are perfectly informed about the market and will rationally forecast how the market will react to unforeseen shocks. The stock-flow model was estimated using adaptive expectations – which gave a good fit to data when applied to the Boston single-family housing market. In contrast to exogenous and rational expectations, the adaptive expectations approach gave cyclical behaviour – the phenomenon that is most frequently observed in housing and real estate markets.

Tu (2004) refers to, and has developed DiPasquale and Wheaton’s model for the Singapore housing market further. The findings are that “in the long run, movements in the real GDP per capita and the total housing stock are found to have significant impacts on real housing prices, while the user cost, the public resale housing prices with one lag explain most of the short-run dynamics of real housing prices”.

DiPasquale and Wheaton’s conclusions regarding adaptive price expectations’ origin from fluctuations based on their stock-flow mathematical model is partially supported by Williams (1987) in an article dealing with price forecasts. An experimental approach combined with survey methodology is used to find price expectations formation. Williams concludes that “the data is found to be generally consistent with an adaptive expectations model. ... However, the model is not stable across experiments. A simple extrapolative expectations model must be rejected as a reasonable approximation of the forecast

formulation process that generated the data”. Williams (1987) also refers to other sources stating that rational expectations – though having considerable appeal as a theoretical model – “does not provide an adequate explanation of actual inflation expectations.....”. “They go on to conclude that an adaptive expectations model that is allowed to vary across individuals and time best describes the price expectations formation process.”

Edelstein and Tsang (2007) present a dynamic approach including demand and supply of housing in terms of econometric methods. Their critic to many other approaches is that either demand or supply relations are analysed. Their conclusions are that “....employment growth and interest rates are key determinants of the residential real estate cycles. However, in general, local fundamentals tend to have greater cyclical impacts than those of national and regional fundamentals”.

Borgersen, Sommervoll and Wennemo (2006) present a model in which macroeconomic and demographic variables are held constant. Price movements are based solely on adaptive expectations. Under these conditions, housing market oscillations after an exogenous price shock are regular, depending on the mortgage income ratio. When they expand the model with endogenous credit rationing, i.e., restrictions on financing depending on assumed asset values, the model indicates that “Periods of mild oscillations are mixed with violent collapses in an unpredictable manner”.

5.4 TRADITIONAL ECONOMETRICS

Considerable amounts of traditional econometrically based sources exist for enlightening questions and problems in the market for housing, the construction industry, but usually not the labour market associated to this particular sector of the community. Some of these approaches are dynamic in the sense that a variable may be dependent on other time lagged variables, but usually there are no feedback loops. Public reports, research projects’ reports as well as publications from academia have been published in order to focus various aspects with a challenging construction sector. The citations that follow are among the most relevant.

The National Bank used a macroeconomic model named RIMINI, in which data from the national accounts are used for forecasting households’ and companies’ exposure to financial

threats, such as debt size and the burden of interest rate (Eklund and Gulbrandsen (2000)). It is difficult to find publicly available documentation of the RIMINI model. Currently, a model for changes in housing prices is described in an article by Jacobsen and Naug (2004). Their model describes factors that influence housing prices. An econometric model is applied for estimation of the effect of the various factors. Employment, housing construction and interest rates are factors that have considerable effects on housing prices. The authors also conclude that housing prices currently (in 2004) not are overvalued in relation to fundamental value related to interest rates, personal income, unemployment and new housing construction. They state that housing prices have more than triplicated over the years 1992-2004, but, prices are not considered to be too high compared to “fundamental values based on interest rates, income levels, unemployment and new housing construction” (quoted). A simplified version of their model is as follows:

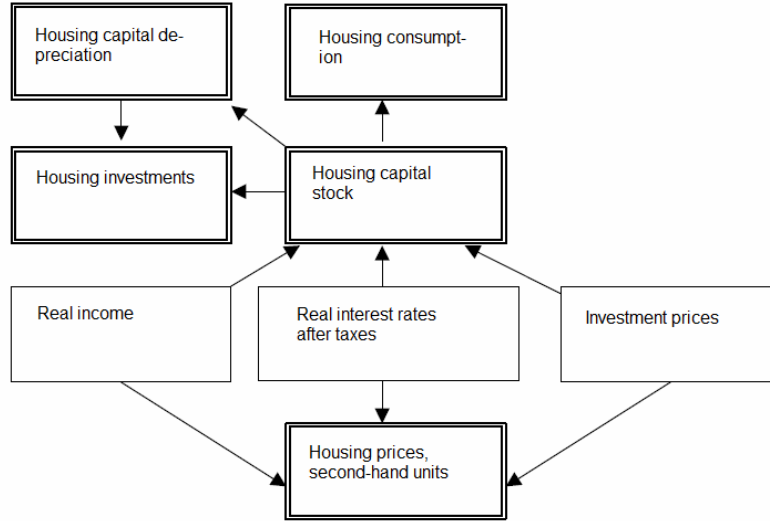
$$\Delta \text{housing_price}_t = 0.12\Delta \text{income}_t - 3.16\Delta(\text{interest_rate}(1-\tau))_t - 1.47\Delta(\text{interest_rate}(1-\tau))_{t-1} + \text{expectations}_t - 0.12[\text{housing_price}_{t-1} + 4.47(\text{interest_rate}(1-\tau))_{t-1} + 0.45\text{unemployment}_t - 1.66(\text{income} - \text{housing_stock})_{t-1}]$$

In verbal description, the change in housing prices is a function of change in income and change in current interest rate adjusted for tax (τ) and change in taxes adjusted for interest rate at time $t-1$, housing prices in $t-1$, unemployment, and, at last income minus housing stock (measured in economic terms) at time $t-1$. This expression, probably with revised coefficients from time to time, is used for forecasting the change in housing prices. This formulation for change in housing prices fit historical data very well for data from 1991 to 2004.

Statistics Norway and the Norwegian Ministry of Finance make use of a macroeconomic model called MODAG. MODAG is also used by Statistics Norway on demand from the fractions in the Parliament's committee for national financial affairs. The model is developed over a long period mainly by Statistics Norway, and re-developed as the structure of the economy changed (Boug (2002)). For instance the housing relations in the model were redesigned in order to meet the terms in the deregulations in the 1980-ies, both for financial markets as well as the housing market itself. MODAG's core structure is an input-output model with add-ons such as a relation for price determination for second-hand housing units, while on the other hand, prices for new housing is determined in the input-output table for prices in the model. The input-output sector of the model determines prices and volumes for

inter-industry deliveries and final consumption, investments of goods and services. The structure of the housing structure of the model is indicated in Figure 8.

Figure 8: The housing block of the MODAG model.



The MODAG model is a model for the general Norwegian economy in accordance with well-known principles of input-output models developed in the middle of the twentieth century. Despite the fact that the name is an acronym for MODEL of Aggregated type, it consists of 28 production sectors including public sectors. The double-lined frames in the figure indicate endogenous variables; the single-line frames exogenous variables. Endogenous in this context is traditionally econometrical – an endogenous variable is determined by a set of exogenous variables. For instance housing price is a function of real income, real interest rates after taxes, and investment prices.

Another Norwegian model is specifically designed in order to deal with the supply and demand in the housing market, the so-called BUMOD model, developed in the 1980-ies in a co-operation between the Department of Economy at the University of Oslo, and Norwegian Institute for Urban and Regional Research. The model documentation is unpublished. The model is very detailed, dealing with active and passive consumers, six different types of housing units, and the model is nationally built up from the 18 different counties of Norway (Barlindhaug (2000)). Long run equilibrium prices are “controlling” the short term price deviations from the long run equilibrium price, assumed to equal long run construction costs. The long run construction costs are exogenous, thus also the long run equilibrium prices. The short run prices are to some extent endogenous, though “controlled” by the equilibrium pre-

conditions from long run equilibrium prices, derived from exogenous construction costs. Housing construction is endogenous.

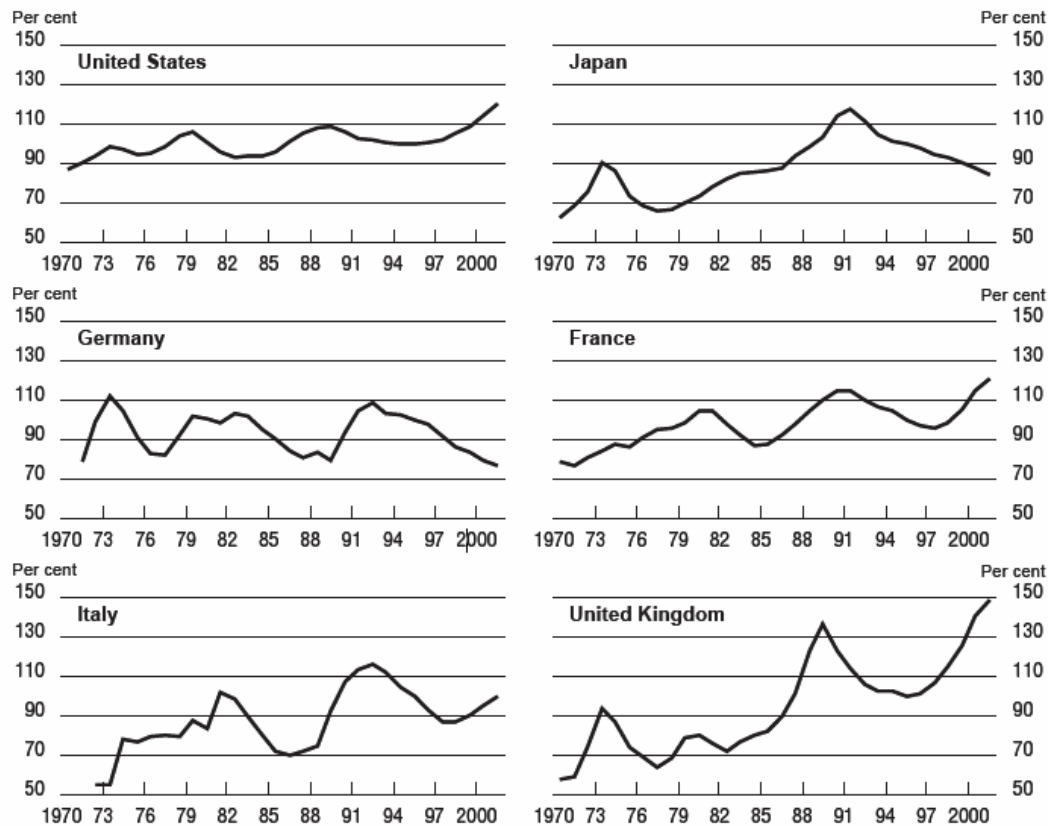
“Tobin’s Q theory” is presented and tested by means of Swedish data by Berg and Berger (2005), a research report of high relevance to Norway due to the parallel developments regarding regulatory regimes and deregulation. The Q theory tells us that investment rates are determined by the ratio of marginal value of capital and marginal value of replacement costs. In terms of housing construction the theory translates to consider the ratio of the marginal housing prices (MHP) in a market to the marginal construction costs (MCC). If $Q = \text{MHP}/\text{MCC} > 1$, real estate developers will have incentives to construct new housing – the profit is positive. Such situations occur when demand exceeds supply. There will be an upward pressure on prices, and consequently an increasing profit margin. The authors presuppose that “Production should stop where $Q \leq 1$ since the profit margin will evaporate. If $Q < 1$ then should it be cheaper for i.e. a buyer to buy a second hand house than a new one. The model also gives indication of the state of the market; a Q-value less (greater) than one signalling excess supply (demand) on the market and unity value indicates equilibrium.” In the report, the Q theory is tested for data from 1980 to end 2003. The conclusions are the following: “Our results indicate, for the last period of the sample (1993 and onwards), that a high degree of correlation between the Q ratio and two measures of housing investment exists. A test with the Johansen cointegration methodology indicates that two different regimes for a long run relationship between the Q ratio and the logarithm of building starts exist. Formulating the investment model as an error correction regression model indicates however a stable long run relationship could be detected for these variables only for the last period;...”. The conclusions for the period 1980-1993 are not considered significant. Berg and Berger (2005) maintain that “For the last period a high elasticity is found between the Q ratio and the logarithm of building starts indicating a prompt reaction from the supply side in the market from changes in demand.”

5.5 DESCRIPTIONS OF CYCLES

Ball and Wood (1999) are using a time series statistical model applied on housing investment data from a number of economies. The data “are decomposed into trend and cycle components in order to find important facets of them”. Their questions were as follows: 1)

Are there long house building cycles? 2) Does volatility vary over time and between countries? 3) Are cycles of housing investment coincident between countries? They found that housing investment is highly volatile both in the short run and in the long run. They found that cycles varied considerably between countries and over time. Cycles have not been coincident between countries, so, for this reason cycles have represented a stabilising element in the world economy, if not for the national economies. They conclude as follows: “These results suggest the importance of investigating the long-run causes of fluctuations in housing investment.The price of housing policies based solely on a partial equilibrium analysis of housing markets may be high in terms of their long-run and macroeconomic consequences.” They found that housing investment is volatile both in the short run as well as in medium run. Housing construction costs have risen substantially, and the authors maintain that the reason for this is not solely because of land scarcity. As an illustration to the findings from Ball and Wood (1999), Figure 9 indicates the fluctuations in real housing prices in various economies.

Figure 9: Real housing prices – nominal prices deflated with consumer price indices – United States, Japan, Germany (West), France, Italy, UK, 1970-2000.



The cycles indicated in the figure do not seem to be strictly regular; however, it seems to be major booms over a range of 6 and 16 years' periods.

In the longer term, and for the situation in Norway, the picture looks like in Figure 10, which indicates that there are short-term cycles and long-run cycles, the latter of a more considerable magnitude. The long-run house price variations are published in Qvigstad, ed. (2004).

Figure 10: Long run price development for the real house prices in Norway 1850-2000, 1912=100. Source: Qvigstad, ed. (2004) and updated figures from Norges Bank (The Central Bank of Norway).

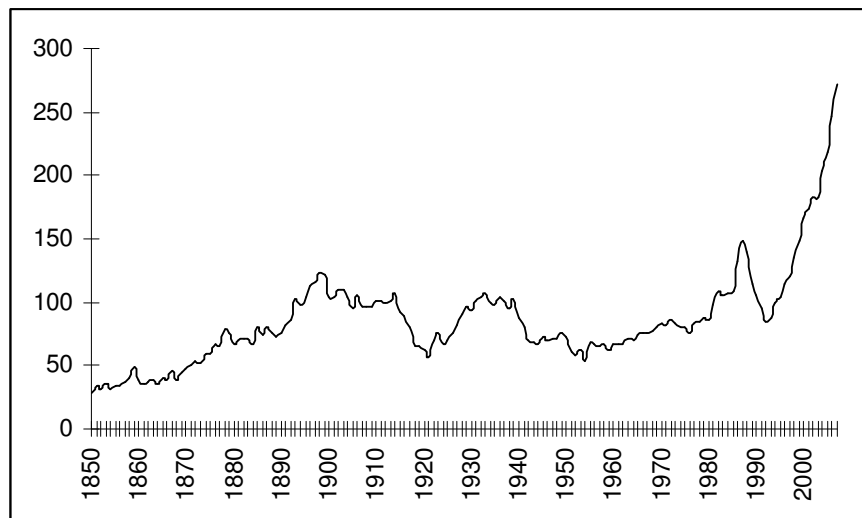


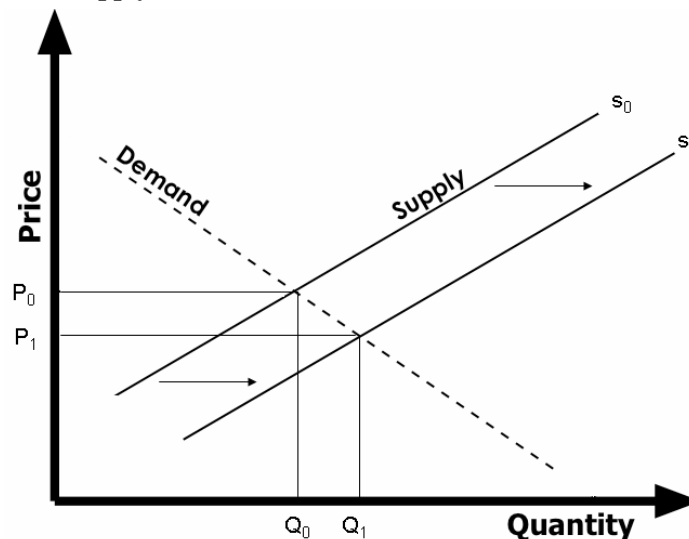
Figure 10 indicates that four major peaks have built up in the Norwegian market over a hundred years. In the 1890-ies a major rental market in blocks of flats was built up, especially characterised by the growth of Oslo (or Kristiania, which was the name at that time). At the end of decade, the so-called “Kristiania collapse” sent prices down, both in Oslo as well as nationally. Prices peaked again in the 1930-ies, with a downturn relative to previous peaks over a long period. The rebuilding period from the end of the World War II and up to the late 1970-ies were characterised by relatively low housing prices compared with the previous price peaks. Prices peaked again in 1987/1988, and then collapsed over the period 1988 to 1993. Recent price level looks like the start of a peak with a probable collapse, and if we are observing a collapse developing just now, it is closer in time since the last collapse, compared to the time between the previous collapses.

6 THE SYSTEM DYNAMICS APPROACH TO HOUSING MARKET MODELLING

6.1 INTRODUCTION

Economists' traditions for explaining markets and market clearing through supply and demand have overwhelmingly been represented by comparative statics – the comparison of equilibrium states before and after an exogenous change. Figure 11 illustrates the static model approach – the higher the price, the higher the supply. The demand is high for a low price, and low for a high price. Equilibrium is the point where the two curves intersect – price and quantity are equal for the supply curve and the demand curve.

Figure 11: Demand and supply curves in the cobweb model

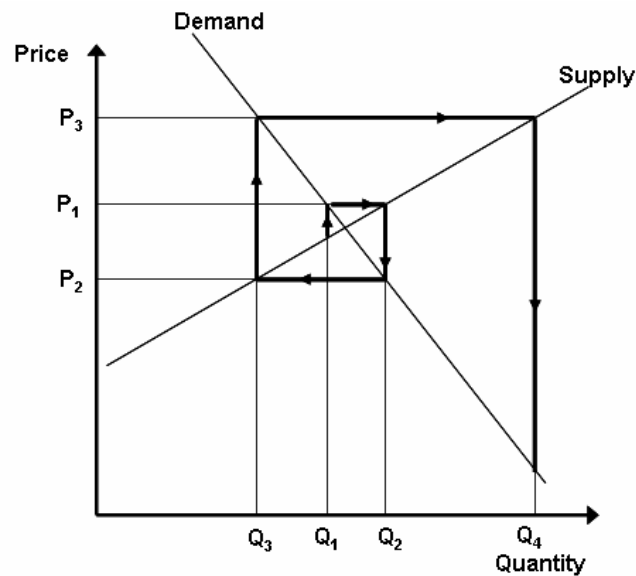


In Figure 11, the supply curve line and the demand curve are “initially” crossing in the point (P_0, Q_0) , which is the point of equilibrium. If the supply curve, for some reason, shifts from S_0 to S_1 , the equilibrium point will also shift. The new equilibrium point is (P_1, Q_1) . A shift in the supply curve may for instance take place when new technologies are introduced in the production of the commodity in question – for any quantity the price is lower for the curve S_1 compared to S_0 . The so-called cobweb model is derived from the original approach presented in Figure 11. The formulation of the cobweb model is the following:

$$\begin{aligned} \text{Supply}(t) &= f[\text{Price}(t-1)] \\ \text{Demand}(t) &= g[\text{Price}(t)] \end{aligned}$$

i.e., the supply is a function of the price in the preceding period, while the demand is a function of the current price. The derivative of f is usually assumed to be positive, while the derivative of g is assumed to be negative – supply curve slope upwards and the demand curve slopes downwards for an increase in quantity.

Figure 12: Demand and supply disequilibrium and adjustments



If we assume that the demand and supply has been moved from the equilibrium for instance from an occasional drop in suppliers' output; the disequilibrium output shown in Figure 12 is Q_1 on the quantity axis. At that quantity the price is bid up to P_1 . If suppliers produce an output in the next period, expecting that prices will continue at P_1 , the corresponding quantity will be Q_2 . Prices drop to P_2 if the suppliers sell the whole output, because customers' demand for this output corresponds to a price P_2 . For this price, suppliers will, in the next period, adjust quantity to Q_3 . At this quantity customers' demand will raise to the price P_3 , in which suppliers will produce Q_4 . In Figure 12 this adjustment process is diverging. The adjustments continuously moves the quantities and prices further away from the point of equilibrium, which is the intersection point of the two curves. The reason for this is that the slope of the supply curve is less than the slope of the demand curve in absolute value. When the slope of the supply curve is greater than the absolute value of the slope of the demand curve the adjustments from disequilibrium will converge against the point of equilibrium. If the slope of the two curves is the same in absolute values, fluctuations will keep going on in a regularly.

In economists' tradition, the supply of housing is considered constant in the short run, for instance as in KRD (2002), in which the supply curve is represented as a vertical line in a graphical presentation as in Figure 11.

According to Meadows (1970), the cobweb model has been represented in verbal, graphical and mathematical analyses and extended almost as far as possible. Though, it relies on the assumption that supply and demand are related to one single variable - price. Meadows maintains that

“...While Nerlove analysed only the influence of a change in the process of price forecasting, it should be clear that the formation of expectations is little different from the investment decision, or the acquisition of production capacity or the maturation (production) of the capacity in its effect upon the dynamic relationship between price and production. All of these invalidate the strict one-period lagged response assumed in the Cobweb Model and thereby alter the system's stability from that predicted by the Cobweb Model.

It is important for those designing control policies to understand the implications of alternative assumptions about each of these four processes, for commodity stabilisation policy may act upon any of them. Theoretically, it is possible to institute producer information systems; to provide restrictions or assistance in changing the level of productive capacity; or to use new breeds, varieties, procedures, or more intensive cultivation to shorten biological and physical delays.

Because one small change in the Cobweb Model, adaptive producer expectations, caused important changes in the conclusions about system stability, it is important to develop a more realistic model which explicitly represents all the processes relating price, production and consumption. Verbal and geometrical analyses were extended to the limit of their capabilities by Åkerman⁶. They will clearly be inadequate for a more complex model. The necessary changes in the Cobweb Model are numerous and include nonlinearities, thus making mathematical analysis also impossible.”

Meadows (1970) includes an extended System Dynamics approach to commodity cycles, based of much of the same assumptions as in the cobweb model. In this sense, the method is convincingly a tool for investigating the housing market, because housing is a *durable*

⁶ Reference to Åkerman's reasoning by means of the Cobweb Model

“commodity” and therefore has an even more complex structure, which leaves the traditional cobweb modelling further behind in relevance for studying the market dynamics.

Economists often claim to have too little data for making proper analyses. According to Meadows (1970): “When an analyst is unable to explain the behaviour of a system, he may 1) Admit ignorance to the system’s structure, i.e., of the important interactions among the system’s elements. 2) Claim that more data is required on the precise value of certain parameters.”----“For administrators a model is sufficiently accurate if it leads them to select the correct policy alternative.”----“The price-elasticities of supply and demand have received more attention by economists than any other pair of parameters.” Meadows points out that it is hardly necessary to have “complete” data sets in order to bring about effective policies.

6.2 THE SYSTEM DYNAMICS METHOD

System dynamics represent a method using feedback and delays. In contrast to traditional approaches to modelling of markets, such as the housing market, feedback is employed in the system dynamics method. Traditional econometrical approaches usually imply the definition of a set of exogenous variables, time lagged or not, that determine the value of one or a few endogenous variables. In system dynamics, variables may determine each other mutually over time through negative or positive feedback loops. Variables may be made endogenous by “closing” a system.

System dynamics is possibly a method that may reveal insights both from the process of modelling the housing market, and from the results of the analyses. The housing market itself has considerable time delays, and there is feedback between the variables, i.e., supply and demand for housing, prices of new and existing units etc.

In the presentation of the problem causal loop diagrams are employed in order to describe the causal relations between variables. Further on, these relations will be translated to more formal entities, stocks and flows.

6.3 SOME NOTES ON NOTATION

6.3.1 CAUSAL LOOP DIAGRAMS

Causal loop diagrams and stock-flow diagrams are employed in order to present the housing market model. Causal loop diagrams (CLDs) are usually used for communicating a problem between the system dynamicist and an audience or a client. CLDs are intuitive but indistinct, but in the first phases of modelling or presenting a structure there is less need for a precise and formal description. The notation is simply to link cause and effect by arrows, and to indicate whether the link is positive or negative. Arrows with a plus sign (+) denote relationships in which a change (increase or decline) in a causing variable make a corresponding change (increase or decline) in the variable that describes the effect (left illustration in Figure 13). Arrows with a negative sign (-) represent relationships in which and increase in a causing variable makes a decrease in the related variable that describes the effect; alternatively that a decrease in the causing variable makes an increase in the variable that describes the effect (right illustration in Figure 13).

Figure 13: Cause and effect, positive from A to B, and negative from C to D



The elements in Figure 13 are combined in Figure 14 in order to illustrate feedback. The left illustration in Figure 14 is a reinforcing loop between the two variables A and B, denoted with (R). If A increases, B will increase, which in turn causes an increase in A. Typical examples are financial capital that increases from interest rate accumulation, and population that grows with a rate determined by the birth fractional rate. The right illustration (the interaction between C and D), is a balancing loop.

Figure 14: Feedback loops, reinforcing (left), and balancing (right)



When C in the balancing loop to the right increases, D will decrease (negative sign); and when D decreases, C will change in the same direction (positive sign). Then, in turn, when C decreases D will change in the opposite direction (negative sign combined with a decrease in the causing variable). A typical example is a population that is depleted by the fractional death rate.

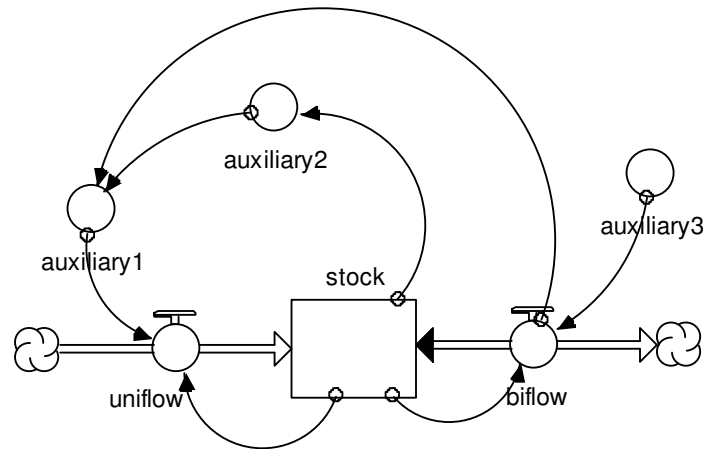
6.3.2 STOCKS, FLOWS AND EQUATIONS

Before presenting model details, some remarks about notation are useful. Firstly, names of variables and parameters are in general not abbreviated. Both in equations and in the description of equations in the text, words in names of variables and constants consisting of more than one word are kept together with an underscore sign, and besides this, in the text written in *italics* when relations concerning definitions are discussed in the model description in chapter 7 “Housing market model”. In other chapters this is relaxed. An example:

equations;	<code>construction_start_rate</code>
text (mainly in ch. 7);	<i>construction_start_rate</i>

Abbreviations and “shorthanding” by eliminating some words that do not make fully understandable variable names occur, but the equations will be of help for interpreting those. Though, one abbreviation should be mentioned - “adj” is short for “adjustment”.

The main elements in the graphical presentation in the following are the sources and the sinks, flows, stocks, auxiliaries and converters, or connectors. An illustration:



In the illustration, the stock is represented by a rectangle, illustrating a “container” that keeps a quantity, either of information, or material. From some undefined *source* on the left of the arrow that points into the stock, the “uniflow” flows into the stock. The inflow in this example is uni-directional – from the source and into the stock. From the stock there is a flow going *out*, however, in this example the flow is bi-directional (this is just an illustration; the flow can also be uni-directional). For a bi-directional outflow, or “biflow”, this implies that for negative values of the biflow, the flow direction is into the stock. The black-shaded end of that flow tells us that the flow “usually” goes out of the stock. The biflows outgoing flow ends in an undefined “sink” to the right of the illustration in this example. The stock, or “container”, represents the delays in the system.

The single-line arrows denote connectors. Connectors connect auxiliaries with auxiliaries, auxiliaries with flows, flows with auxiliaries, and stocks with auxiliaries.

The auxiliaries are either functions/variables, endogenous or exogenous, or constants. In this example, auxiliary1 is defined as a function of the biflow and auxiliary2, which is a converted value of the stock.

In the model elaboration in the following, stocks will in general not be described by equations. In a general form, with flow names as in the illustration above, the stocks always have this structure:

$$\text{stock}(t) = \text{stock}(t - dt) + (\text{uniflow} - \text{biflow}) * dt$$

INIT stock = { initial value }

i.e., “stock at time t equals stock in time t minus timestep (dt) plus unflow times timestep minus bflow multiplied with the timestep”. Initial stock values have to be defined, either analytically by an equation defined by inflows and outflows, or a desired value, or by a number.

6.4 MODEL OVERVIEW

In “traditional” econometric models, one single endogenous variable and a number of exogenous variables are basis for estimation of coefficients by a variety of statistical methods. The coefficients explain the extent of effects from the various exogenous variables to the endogenous variable. For instance, demand for housing (in traditional econometrics) is expected to depend on interest rates, employment, income per capita, in some models expectations indices, and so on. One single variable is explained by a number of other variables.

In the current thesis the variables, as far as possible, are made endogenous, which also is the aim of system dynamics’ traditions. The following listing indicates endogenous and exogenous variables, and which variables and structures, possibly important or relevant that are left out.

Endogenous	Exogenous	Excluded
<ul style="list-style-type: none"> • Housing prices • Cost (of construction) • Housing demand • Under planning (i.e. housing) • Under construction • Housing stock (i.e. housing supply) • Labour • Jobless • Recruits 	<ul style="list-style-type: none"> • Price elasticity • A set of parameters, i.e., adjustment times • A set of table functions • Labour productivity 	<ul style="list-style-type: none"> • Debt • Financial sector • Housing expenditures • Wages • National economy • Leisure homes • Rest of construction industry • Construction ground

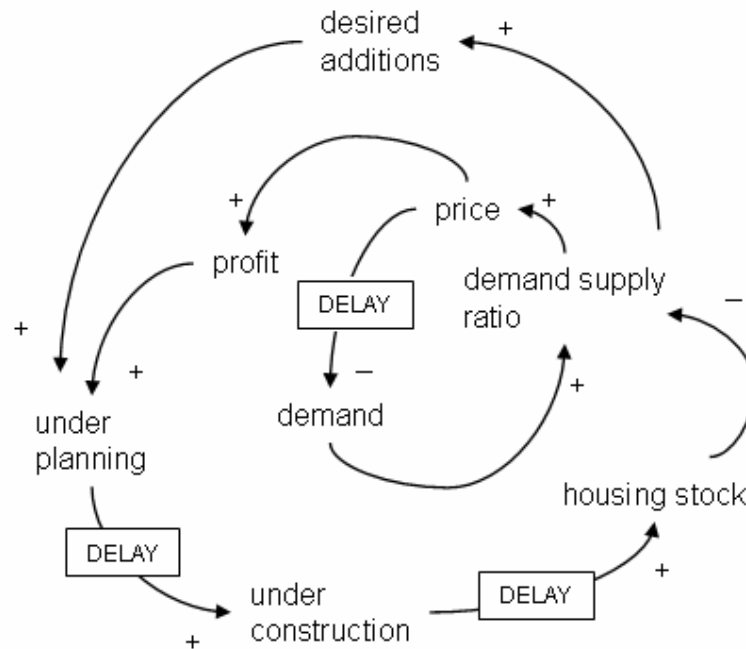
6.4.1 HOUSING MARKET OVERVIEW

Figure 15 shows the housing market sub-model overview in a causal loop diagram. The most important variables and loops are indicated. The general market model overview indicates the two longest delays, one from housing planning prior to construction, the next from construction to completed housing, represented by housing supply, i.e., the total housing stock. These time delays are considerable – the planning to construction delay might be several years⁷. The construction delay is one to two years, depending on category of housing. Other delays exist as well; however, these are not represented in this general overview. These will be indicated in the model elaboration of a formal model in stock-flow diagramming and the related equations in later chapters.

The outline of the housing market in Figure 14 has three major loops. The first loop is represented in the middle of the figure, and, if we may start tracing it from the demand/supply ratio to price, then through demand and back to the demand/supply ratio again. If price *increases*, demand will decline. This complies with the common assumption for most goods. When demand declines, the demand/supply ratio⁸ will decrease. This, in turn, will give a pressure on prices to *decrease*. This is contrary to the initial assumption about the initial price movement. This is a balancing loop.

⁷ Municipal authorities usually have a long planning time horizon. However, from one to three years has been indicated as “normal” planning time, the longest times for multi-dwelling buildings, and, depending on whether areas are prepared for housing construction.

⁸ If demand and supply are defined as functions of price, the demand/supply ratio may be defined as the ratio of the inverse of the demand and supply curves usually presented in economic textbooks; $(-a \cdot \text{quantity} + b) / (c \cdot \text{quantity} + d)$; a, b, c, d greater than zero, the numerator will decrease if quantity declines. Hence, the ratio will also decrease.

Figure 15: Housing market demand and supply structure.

Starting at price again, the next loop goes through profit to housing under planning, then to housing under construction. From construction housing is completed and adds to the total stock of housing, then to the demand/supply ratio and back to price again. If price *increases*, profit will increase, so also housing under planning and construction, and the housing stock. The demand/supply ratio on the other hand will decrease; the denominator in the ratio increases. Then price also will *decrease*, which is the contrary to the initial assumption for the price. Accordingly, this loop is balancing. This is a profit motivated supply loop.

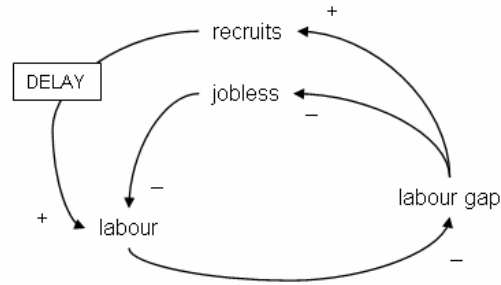
The third loop, if the starting point is an *increase* in desired additions; this will increase housing projects under planning, then housing construction, which increases the housing stock. When housing stock increases, the demand/supply ratio will decrease, which, in turn results in a *decrease* in desired additions, which is the opposite of the assumptions from the starting point. This loop is also balancing. This loop reflects the observed demand, either by direct request from customers or by the recognition by real estate developers that there is a trend of demand shortage related to supply.

The variable “under construction” represents the link between the housing market sub-model to the capacity sub-model. We may also have included the “under planning” to another capacity sub-model, however, this is left out.

6.4.2 CAPACITY UTILISATION AND CAPACITY ADJUSTMENT

The delay for building new capacity may vary, depending on whether capacity is infrastructure, i.e., offices, storehouses and machines, or labour, i.e., engineers, planners and architects in planning activity, and craftsmen and unskilled labour in construction activity. Both in the causal loop diagramming as well as for the more formal system dynamics model and related equations, only labour in housing construction will be used. Figure 16 shows the structure of the long term construction capacity system in a simplified approach.

Figure 16: Structure of the capacity sub-model; recruitment of jobless and additional labour



There are two loops in the capacity sub-model, the “re-recruitment loop” and the “new recruitment loop”. Starting with the *labour_gap*, the “re-recruitment loop” (*desired_labour* minus *labour*) passes on to *jobless*, then to *labour* and then back to *labour_gap* again. If the *labour_gap* increases, *jobless* decreases (through hiring), and when *jobless* decreases, *labour* will increase, which in turn closes the *labour_gap*, it will *decrease*. That is contrary to the starting point, an *increase* in *labour_gap*. Therefore this is a self-correcting, or a balancing loop. The other loop is the acquisition of additional capacity. Starting at an *increasing labour_gap* again, this will increase the recruitment of additional unskilled *recruits*, which increases the *labour* stock. This, in turn, will *decrease* the *labour_gap*. In other words, this is another balancing loop in the capacity sector.

Recruitment of *jobless* takes less time than recruiting new capacity. Jobless in the construction industry have been trained, more or less, and may go into positions to do productive work relatively quickly. For skilled and so-called unskilled labour (with a practice in the industry) a re-engagement typically will take weeks or a few months.

Recruits, on the other hand, either need formal education or training. Recruits are not in general as productive as skilled workers, and they need guidance from skilled workers and “mentors”, that further reduces the overall productivity per worker. When it is known that there is a need for additional capacity, it takes time for individuals to decide on whether or not to enter a career in the industry, and education, formal or by practicing, will take time. This represents a considerable delay in the acquisition of additional capacity. Even more, this applies to the planning functions, such as education of engineers, planners and architects. However, the latter is not part of the analysis. Planning staff, architects etc. typically have a four to five years education, and, additionally some years of practicing. Recruits to construction need a couple of years in vocational schools and further two to three years as apprentices before they are considered qualified.

7 HOUSING MARKET MODEL

7.1 THE SUPPLY CHAIN

The stocks in the supply chain include housing under planning and housing under construction. Construction completion adds housing to the existing housing stock that is the total supply of housing.

Profitability is an important prerequisite for housing construction activities. When profitability is considered acceptable, decisions on construction will take place, however, limited by the planning and construction capacity. Decisions are based on expectations – the relation between *expected* price and *expected* costs, which may deviate from actual price and costs. When construction is decided upon, there is a time-consuming process from initiation to supply of final housing, ready for buyers or self-builders to move into. For already regulated areas from the hands of the authorities, we are at a range of a year or two depending of the type of housing. Unregulated areas, on the other hand, take several years to prepare for housing construction.

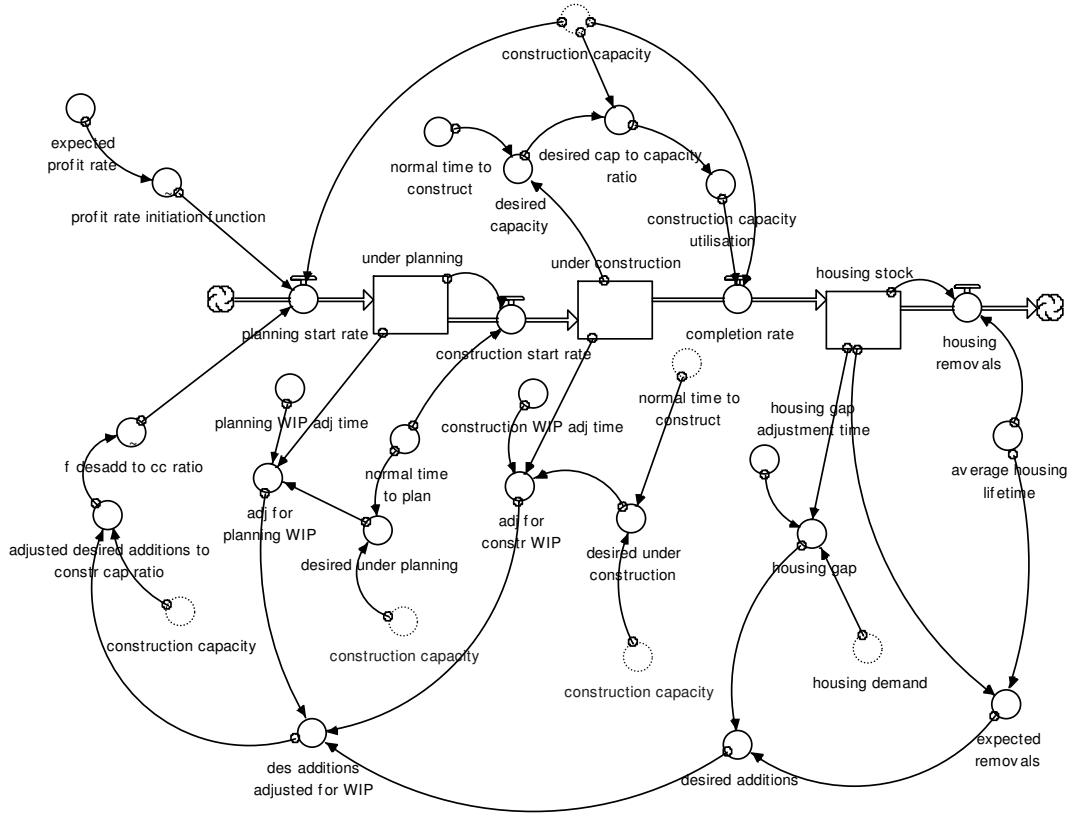
When construction area and plans are available, and construction is expected to be profitable enough, there is a period from about 8 months to two years before housing area is available for potential buyers, depending on the type of housing. Construction of detached housing takes less time than for instance construction of multi-household apartment blocks. In addition, the condition of the actual site for construction will also determine both construction time and probably also construction costs.

The amount of areas regulated for housing depends on the public planning capacity and ability. In some cases there are certain rules for the time horizon of this planning. Usually authorities are planning and regulating for the longer term, both for the construction ground itself as well as for infrastructure, such as schools, kindergartens, roads and transport, water and energy supply, etc. In a report the Norwegian Ministry of Local Government and Regional Development (KRD (2004)) maintains that “Studies indicate that the supply of land for housing purposes is for the most part satisfactory, although certain challenges exist with

regard to achieving more straightforward, rapid processing of planning regulations for housing purposes.”

The “main chain” for housing planning, construction and completion to the existing housing stock, of which the latter in this context is the supply of housing⁹, is presented in Figure 17.

Figure 17: The housing supply chain



The supply chain starts with the flow *planning_start_rate* to the left in the figure. The *planning_start_rate* feeds into the stock *under_planning* (the input to the planning start rate will be discussed later). The authorities’ general area planning ordinarily has a long term horizon in order to meet demand for construction ground in the “foreseeable” future. The normal time to plan therefore refers to planning in actual construction projects, usually in the

⁹ In this context the total stock of housing represents the supply, not the additional housing from construction completion

range of 1-3 years¹⁰. From housing *under_planning* there is a flow, *construction_start_rate*, which pass on as completely planned housing to the stock *under_construction*. The *construction_start_rate* in this model is defined as

$$(\text{construction_start_rate}) = (\text{under_planning}) / (\text{normal_time_to_plan})$$

If for instance the amount of projects under planning equals 100, and the normal time to plan is 2 years, the construction start rate will be 50 projects per year, or the half the quantity of projects under planning. There are no capacity limitations for planning in the base model; however, such limitations could have been employed. For the completion rate, a capacity limitation process is used.

From *under_construction* there is a flow *completion_rate* to the *housing_stock* that should be interpreted as the total supply of housing. The *completion_rate* is defined as follows:

$$(\text{completion_rate}) = (\text{construction_capacity}) * (\text{construction_capacity_utilisation})$$

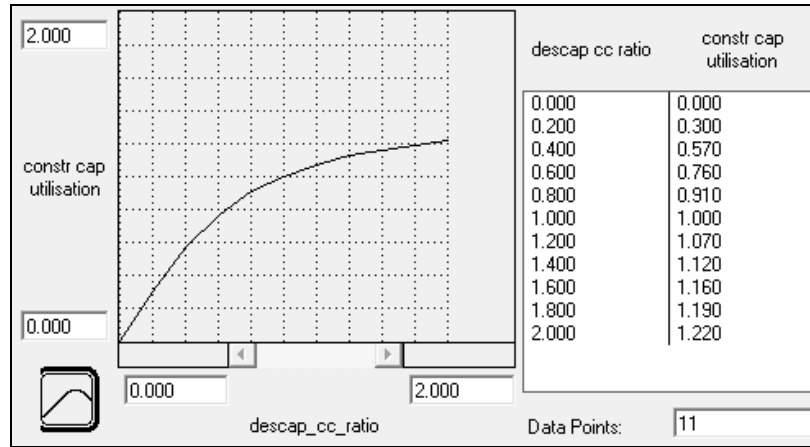
in which

$$(\text{construction_capacity_utilisation}) = \text{function}[(\text{desired_capacity}) / (\text{construction_capacity})]$$

The *construction_capacity_utilisation* (CCU) is defined as a table function (see equation list in Appendix 2A). The function is concave, starting in (0,0) and intersecting (1,1). In unity there is a “normal” capacity utilisation and a current time to construct equal to the normal time to construct. When *desired_capacity* is greater than the *construction_capacity*, the CCU is greater than one, and the construction capacity is utilised more extensively. When CCU is less than one, the capacity is *gradually* less utilised, allowing the real construction time (i.e. *under_construction* divided by *completion_rate*) to be lower than *normal_time_to_construct*. Figure 18 illustrates the shape of the function.

¹⁰The current procedure time at for instance the Agency for Planning and Building Services for approval of new projects, for instance in Oslo, is 31 weeks for detached housing which not is completely projected in advance, and for larger projects. First, developers must apply for a “General Permit”. Prior to that, it usually takes 25 weeks from decision of developing a project prior to a request for a General Permit, according to an interview with a developer. General Permits are given when projects correspond with existing local plans, and the authorities’ ambition is to process the plans within 12 weeks. Before starting the construction process, the developers have to apply for a “Project Start-Up Permit”. According to the interviewee mentioned above, the time from a General Permit is given to construction start (including Project Start-Up Permit) usually takes 25-35 weeks, however, the time span is wide – 8 to 52 weeks. In this phase the pre-sales process take place, and the prerequisite for starting construction is at least 60 per cent sold units (in larger projects). In average, a total of approx. 90 weeks are indicated for the duration of the planning. In the simulations 1 to 3 years will be used, with a base value 1.5 years.

Figure 18: The relationship between the ratio (desired construction capacity)/(construction capacity) and the construction capacity utilisation.



Supposedly, the *planning_start_rate* will depend on the profitability of starting new housing planning and construction. If prices for existing housing in general are lower than the costs of construction, potential buyers will tend to prefer buying from vacant existing stock, however, some individuals will prefer to build anew, less dependent of cost-price relationship. Therefore, housing construction will not necessarily come to an end when profitability is low.

The *housing_stock* is drained by the flow *housing_removals*, which include departed houses, burnt-down or in any other way destroyed housing, housing left to other purposes, etc. Housing is also rebuilt or refurbished; housing units are sometimes combined, in other cases broken up to a larger number of units. In principle, this also represents removals and finally construction. In the base runs of the model, average lifetime for housing has been set to a hundred years. Estimates are rare; Van der Flier and Thomsen (2006) have an estimate of 350 years¹¹. In this context the of removals definition is

¹¹ They state that “The overall picture of the demolitions in the Dutch housing stock shows that the demolition rate is roughly 0.2 to 0.3% of the housing stock, which is substantially higher and much more increasing than in the surrounding countries”. Further they maintain that “Regarding the often precalculated economical lifetime of 50 years the actual demolition rate might be considered as far too low.”

The demolition rate refers to the physical lifetime of buildings. Van der Flier and Thomsen (2006) refer to a variety of definitions, among them also OECD’s “service life”. The Norwegian term “avgang”, which is closest to “removals” in similar connections, imply that housing is unoccupied or physically destroyed. In the short run changes of use by combining smaller units to larger, or breaking up larger units to smaller, will imply that housing is left unoccupied for some time

A hundred years life cycle is an “estimate” used throughout the thesis, except when testing for sensitivity and behaviour reproduction.

$$\text{removals} = (\text{housing_stock}) / (\text{average_lifetime})$$

that also is the definition of *expected_removals*, which converts to *desired_additions* together with the *housing_gap*, the difference between *housing_demand* and *housing_stock*, i.e., housing supply, adjusted with the *housing_gap_adjustment_time*. The definition of *desired_additions* is as follows:

$$(\text{desired_additions}) = (\text{housing_gap}) + (\text{expected_removals}) \quad \text{in which housing gap is defined:} \\ [(\text{housing_demand}) - (\text{housing_stock})] / (\text{housing_gap_adjustment_time})$$

The term *desired_additions* represents “observable” demand in for instance direct requests for housing construction from customers, and the construction industry players’ knowledge, or judgement, of potential divergences between demand and supply. Desired additions and construction capacity feed into the *des_additions_adjusted_for_WIP*, or “desired additions adjusted for work in progress”. This is an option for the policy discussion, and does not have relevance for the base runs to be performed. The *des_additions_adjusted_for_WIP* feeds into a function that in the Figure 17 is denoted *f_desadd_to_cc_ratio*, defined as follows:

$$f_desadd_to_cc_ratio = \text{function}[(\text{desired_additions}) / (\text{construction_capacity})]$$

This represents a smoothing function as construction capacity changes. The shape and operation of this function is similar to the function illustrated in Figure 18; concave, starting in (0,0) and intersecting (1,1). If *desired_additions* and *construction_capacity* equals, the functions value will be 1, and the input to the *planning_start_rate* equals unity multiplied with *construction_capacity*. However, a profit based formulation is also input in the *planning_start_rate*, so, the complete definition of the *planning_start_rate* is as follows:

$$(\text{planning_start_rate}) = (\text{profit-rate-initiation_function}) * (\text{construction_capacity}) * F[(\text{desired_additions}) / (\text{construction_capacity})]$$

The *profit_rate_induction_function* (PRIF) is a table function. If relative profit, defined as the following,

$$\text{profit_rate} = [(\text{expected_price}) - (\text{expected_cost})] / (\text{expected_cost})$$

is zero, PRIF is assumed to be one¹². For values of the profit rate less than zero, the PRIF will be less than one, with a dampening effect on planning and consequently construction. For positive profit rates, PRIF is greater than one, and increasing for increasing profit rates, though, within a range. The PRIF meets the assumption that profitability counts in decisions of starting new housing construction, and that increasingly less projects will be realised when the profit rate turns negative. One reason for this is that already existing housing can be bought to a lower price than building new housing, even if there is a surplus in housing demand related to housing supply at the moment. Or, in the case of refurbishing, other reconstruction and other elements from the flow *removals*, buying other second-hand objects is less costly. Though, we may find reasons for desires to start new projects even if the profit rate is negative. Among other things, individuals' valuations, and individuals' considerations about the future market situation may count. When PRIF is equal to one, all desired additions, but nothing more, will be passed on into the *planning_start_rate*. On the other hand, when PRIF is greater than unity, PRIF reflects the profit motivation, which, in addition to desired projects from the already “observed” need from the discrepancy between housing demand and housing supply including replacement of removals, increases planning start rate as a multiplier.

The housing planning, construction and supply chain has two major loops. The first one is from *planning_start_rate* (we assume an *increase*), via the chain to *housing_stock* that will also increase, then passing through *expected_removals*, then to *desired_additions* etc., ending where we started - the *planning_start_rate* – with an increase, i.e., a positive loop. The other major loop starts at *planning_start_rate*, passing through the construction chain, and ending at the *housing_stock*, then from housing stock to “housing gap”. When the *planning_start_rate* increases, the housing stock will increase, causing the housing gap to *decrease*, consequently also desired additions and planning start rate will decrease, contrary to the starting point – an *increase* in the *planning_start_rate*. This element gives a negative or balancing loop.

¹² This does not necessarily imply that real estate developers and housebuilders require that all “desired additions” qualify to realisation when the profit is zero. Actually, developers ordinarily require more than 10 per cent profit for their projects to be carried out. For the model to be initialised in equilibrium, the curve for PRIF as defined in this context pass through (1,1). An expected profit rate that equals zero may be interpreted as an expected profit including the required mark-up, but not “super profits”.

Events are anticipated by introducing two additional adjustment options in the layout of the model. These will not be parts of the base run, but will be discussed further in the sensitivity testing and in the policy considerations. These adjustments are the following:

Adjustment for construction work in progress (WIP), defined as follows:

```
adj_for_constr_WIP = (desired_under_construction-under_construction)/construction_WIP_adj_time,
in which
desired_under_construction = construction_capacity*normal_time_to_construct
```

The *construction_WIP_adj_time* represents “adjustment time of construction work in progress”.

Adjustment for planning work in progress is defined as follows:

```
adj_for_planning_WIP = (desired_under_planning-under_planning)/planning_WIP_adj_time
in which
desired_under_planning = construction_capacity*normal_time_to_plan
```

The *planning_WIP_adj_time* represents “adjustment time of planning work in progress”.

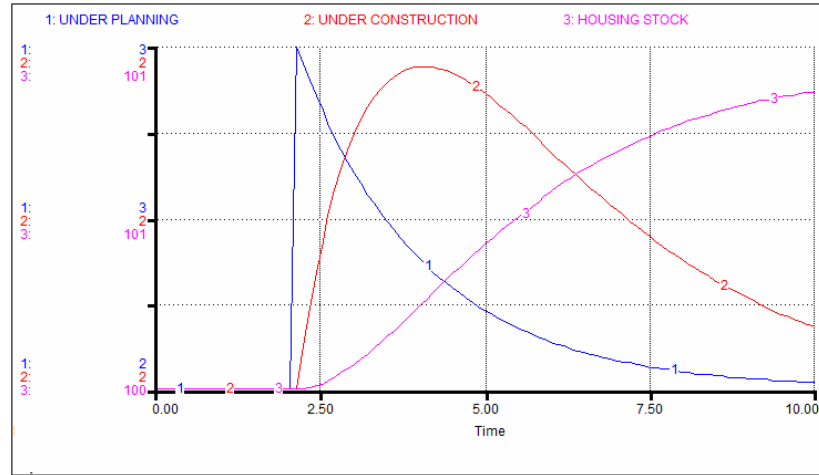
These adjustments modify *desired_additions* up or down, depending on the quantity in the “planning pipeline” and the “construction pipeline”. The two adjustment loops are balancing. In the base runs the WIP adjustments are set to zero. Therefore the *des_additions_adjusted_for_WIP* equals the *desired_additions* in the base run.

The formulations for the adjustment processes above has a similar effect as the supply line management process in Sterman (2000), however, the formulations above are not exactly the same. In Sterman the desired values are based on a variable equivalent to *desired_additions*, not *construction_capacity* that is used here. In this housing model the WIP adjustments have an overshooting effect that does not allow adjustment fast enough. For example with a step increase in demand, the profit will remain positive over a very long time, however, that formulation gives dampened cycles compared to the base run, i.e., without correction for the supply line. The chosen alternative is a corresponding variable for *desired_additions* when the model is in equilibrium, namely the *construction_capacity*.

The supply chain with stocks causes delays. This is illustrated in Figure 19, in which the supply chain initially was in equilibrium, i.e., the flows into and out of the stocks were equal.

A pulse input added to the planning start rate (here at time=2) causes *under_planning* to rise sharply.

Figure 19: The isolated effect of a step input in planning start rate for housing under planning and construction, and the housing stock

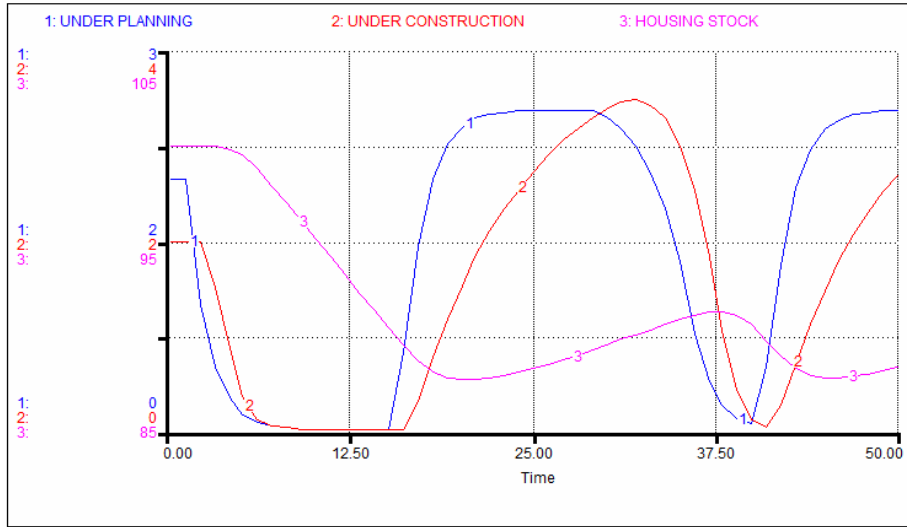


As the higher volume of housing under planning is completed, housing under construction will increase, however delayed in relation to the housing under planning. The change in the housing stock is even more delayed, caused by the stock *under_construction*, which represents a delay, and the completion time, that has an influence on the delay. The full effect of the pulse input takes several time units. This is an important aspect. If housing construction is profitable and the planning start rate increased, the final delivery of housing will increase over many years, even when profitability turns negative. This is caused by the delays when housing initially planned are delayed in the planning and construction process to the final housing

The structure of the supply line presented in Figure 17 creates cycles because there is one major reinforcing loop and one major balancing loop. The balancing loop will overshoot and undershoot the effect of the reinforcing loop. The reinforcing loop goes from *planning_start_rate* through the supply line to the *housing_stock*, thereafter to *expected_removals* which finally feeds into the *planning_start_rate* through positive links. The balancing loop goes from the *planning_start_rate* through the supply line to the *housing_stock*, and then to the *housing_gap*, which has a goal-seeking function by the statement *housing_demand* minus *housing_stock*. If for instance housing demand is greater

than housing supply, the gap is positive, and this increases *desired_additions*, while on the other hand, when demand is less than supply, the gap is negative, which adjusts *desired_additions* down. The oscillatory behaviour with a ten per cent decline in *housing_demand* is shown in Figure 20.

Figure 20: The behaviour of the supply line with feedback from expected removals and housing gap



7.2 CAPACITY

7.2.1 INTRODUCTION

As in every other industry, the housing construction industry depends on chains of input. While other industries than housing constructions fluctuate considerably less, the input chains in construction will be more critical with respect to certain resources. Planning and construction capacity in terms of employees are perhaps the most important.

Transportation is fundamental for bringing materials to places where construction take place, especially because construction is located to the place where final delivery will occur; completed housing will not be moved¹³. Much of the same reason, housing is constructed for

¹³ Either housing is pre-fabricated or more or less completely built on-site, transportation will take place

immediate sale or use, and ordinarily not produced for keeping as a reserve, which usually is the case for commodities.

Transportation in housing construction represents, in monetary values, 3.4 percent of input to the housing construction sector's total input cost in general. For all industries in average, transportation represents approx. 10 percent of the total input according to input-output tables for the Norwegian economy. For this reason, the transport industry is probably not the most critical bottleneck in housing construction. Transportation companies may have a reserve for keeping up with fluctuations in one single industry, such as housing construction.

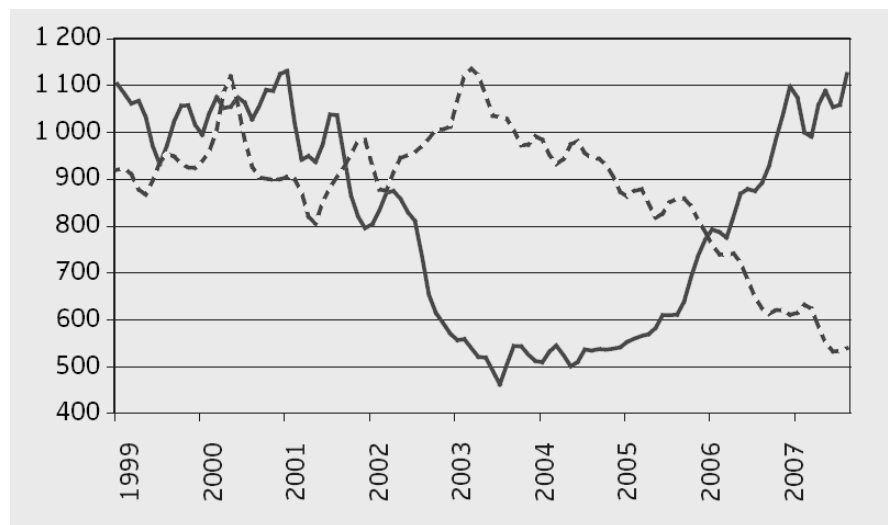
Sometimes shortages of certain materials may arise, specifically for building materials. However, since different economies' cycles not necessarily have the same time phases, a shortage in one market may be compensated by affluent capacity other places. Since such reallocations may take time, and since reallocations require transport, this may to some extent be critical for the housing construction industry. Recently there has been a shortage of certain materials, such as insulation materials, plaster wallboard, concrete building elements and wooden materials. For instance for the delivery of insulation materials, such as glass fibre padding, it was reported that the delivery delay peaked at four months in February 2007¹⁴ - builders hoarded certain building materials. Building materials have perhaps not, as today, been such a bottleneck for construction activity since the 1950-ies, when rebuilding after the World War II took place. At that time, governmental directives were employed in order to put a ceiling on resources in order to achieve certain goals for the authorities for the difficult housing situation for a major part of the population in Norway. Kiøsterud (2005) states that already in 1941, during the Second World War, a temporary regulation for the construction industry was implemented - in English: "Temporary Law for the Regulation of Building and Construction for the Purpose of securing Economic Stability." The bottlenecks were thus defined beforehand, and the intention of the regulation was to secure stability in a situation with scarce material resources to the construction industry.

Human resources specific for the industry, such as skilled workers in housing construction, area planners, architects, housing construction engineers are probably the most

¹⁴ source: <http://forbruker.no/bolig/nybygg/article1655247.ece> (as of 27 September 2007)

critical kind of resources in cyclical industries, such as construction. Currently there is a considerable shortage of planners, engineers, architects and skilled housing construction workers. Even for unskilled labour, which also is an important resource for the construction industry, recruitment problems prevail as the economy in general works close to capacity limits. To some extent, unskilled labour substitutes skilled labour in construction – though probably at the cost of quality.

Figure 21: Announced jobs (dotted curve) and job applicants (blue curve) 1999-2007. Source: NAV (2007)



Planning at the authorities' level and planning for real estate developers imply competition for much of the same kinds of human resources. Particularly architects and construction engineers are involved both in planning at the general level and for the housing construction projects – both for authorities and for the developers. In general, authorities' flexibility in competing with private actors for workforce is hampered, resulting in a drain of competence from the authorities to the benefit of developers in during expansion, and vice versa, during recessions. Planning capacity at both levels, the authorities' and developers', is a scarce resource which takes long time to replace or adjust. 5 to 6 years of education, and perhaps 2-5 years as practitioner is probably required in order to become qualified staff members in general housing planning for the authorities, and for real estate developers.

In the same way as for planning and development activities, housing construction is depends on capacity build-up if capacity is unavailable at the moment. Even if labour is available it will take time to build efficient capacity - "3-5 years is required to build an efficient contract team" (i.e. a team of workers who are paid according to work results);

expressed by a researcher who previously had worked as carpenter in building and construction. Capacity counted just in man-years is an insufficient measure, achieving efficiency takes time.

Additionally, recruitment of labour to the construction industry takes a long time. To achieve required skills in construction, at least for the more specialised jobs, a two year theoretical/practical education at college level is needed before recruitment to an apprentice position in companies approved for apprentices' trainee employment.

Also in the case of so-called unskilled workers, skills are preferable. So-called unskilled labour is labour without formal education, and skills are developed through practice. Therefore we may expect that so-called unskilled labours' skills not are efficiently maintained when hiring is cyclical. When these workers are jobless for longer periods, they will probably to a higher extent tend to move to other job markets, compared to those who are educated for working in the housing construction industry. This drains competence.

7.2.2 THE HOUSING CONSTRUCTION LABOUR MARKET

From the supply sector of the model, *desired_capacity* enters the labour sub-model, and *construction_capacity* is the output to the market sub-model. The labour market model has three stocks - *recruits*, *labour* and *jobless*. Figure 22 illustrates the model structure.

The labour market model is compacted. For instance, labour is not homogenous in the real world – in the model this fact is not taken into account. Furthermore, vacant jobs are *usually* announced. The model does not include that detail. However, the main issues have been taken into consideration: The housing construction sector has demonstrated considerable fluctuations in employment, and, it takes time to recruit and develop skilled workers.

Construction capacity converts into *desired_labour* as follows:

$$\text{desired_labour} = \text{desired_capacity} / \text{productivity}$$

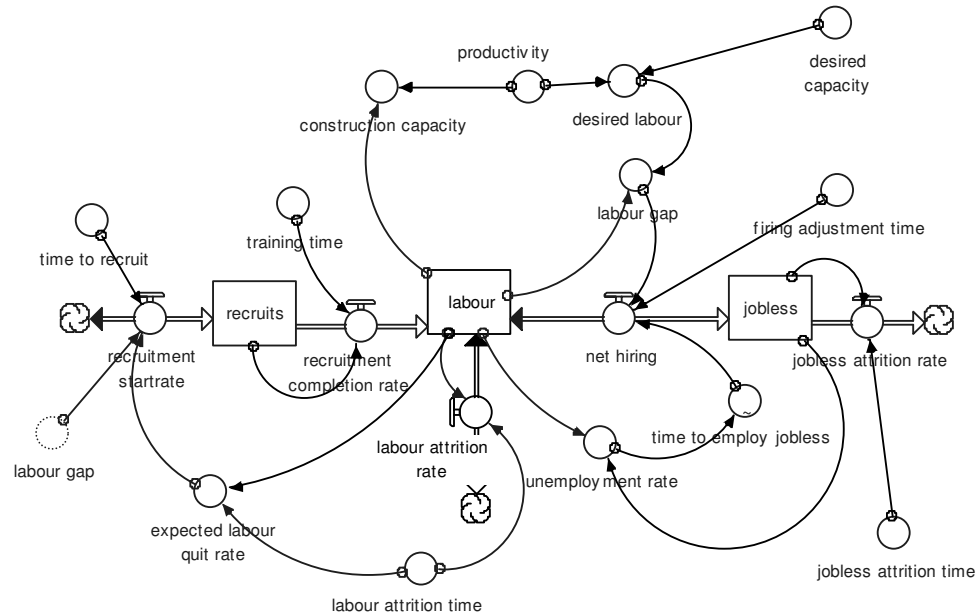
in which productivity is in terms of an indicator, for instance square meters per worker.

An essential part of the labour sub-model is the migration between the stock of employed *labour* and the *jobless*. The flow from *labour* to *jobless* is defined as a bi-directional flow with one adjustment time for quitting and one variable adjustment time for re-hiring of *jobless*. Workers might be noticed to quit or sent on leave when desired capacity is lower than actual – workers are permanently or temporarily getting jobless. On the other hand, jobless might be recruited again when *desired_capacity* exceeds *construction_capacity*. The flow corresponding to this in the model is the *net_hiring*, defined as:

$$\text{net_hiring} = \max(0, -\text{labour_gap} / \text{firing_adjustment_time}) - \max(0, \text{labour_gap} / \text{time_to_employ_jobless})$$

in which
 $\text{labour_gap} = \text{desired_labour} - \text{labour}$

Figure 22: Capacity (labour) sub-model



The two main components on the right-hand side of the equation for *net_hiring* state that a maximum value shall be in effect for each of the two components. The first component in the equation might be called the “firing component”. That element states that if the *labour_gap* is negative (desired minus actual is less than zero), this component is positive, and therefore also the max value, i.e., firing take place. When *desired_labour* is less than current *labour*, the second component of the right-hand side of the equation for *net_hiring* is zero – there is no (net) re-recruitment of *jobless* when there are more employees than desired. Similarly, when *desired_labour* is greater than *labour*, the first component on the right-hand side of the equation has value zero, while the second component will be negative, i.e.,

negative related to the direction of the flow *net_hiring*, which means that the flow turns the direction, becoming a flow from the *jobless* to the *labour* stock.

The *unemployment_rate* is defined as the relative unemployment:

$$\text{unemployment_rate} = \text{jobless}/(\text{labour}+\text{jobless})$$

The unemployment rate is input to the *time_to_employ_jobless*, which is a table function (see the Appendix 2A for definition). The is very large when the *unemployment_rate* is close to zero, and getting smaller for increasing values of the *unemployment_rate*. This function is defined this way in order to take into consideration the effect that when joblessness is decreasing, the recruitment of *jobless* increasingly takes more time. On the other hand, when there are many jobless, the re-recruitment takes place very rapidly.

A number of workers as well as jobless will retire or get other jobs, and *recruits* will complete education. These effects are reflected in the flows *labour_attrition_rate*, *jobless_attrition_rate* and *recruitment_completion_rate* that drain the stocks of *labour*, *jobless* and *recruits* respectively. These three rates are defined similarly, and for the *labour_attrition_rate* the definition is:

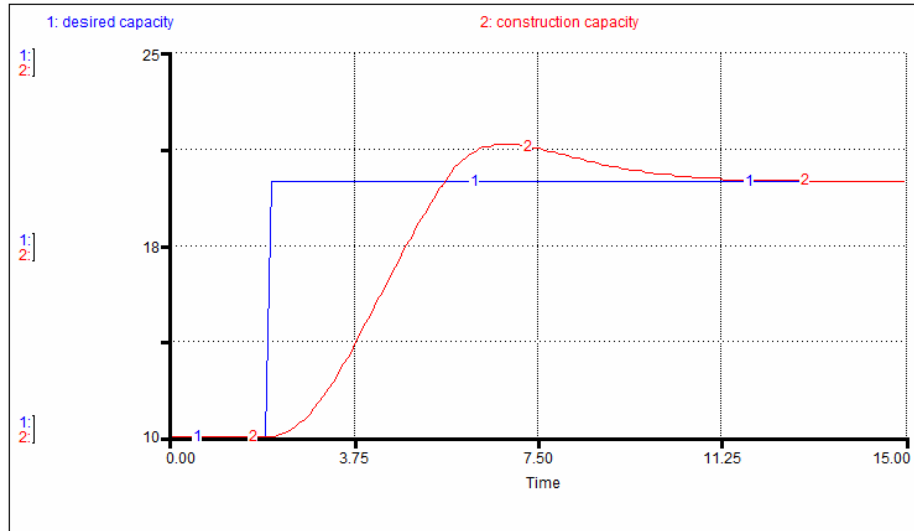
$$\text{labour_attrition_rate} = \text{labour}/\text{labour_attrition_time}$$

When *desired_labour* is greater than *labour*, and there are no more *jobless* left to hire, the recruitment of additional workforce has to take place. The inflow to the *recruits* stock is defined as the following:

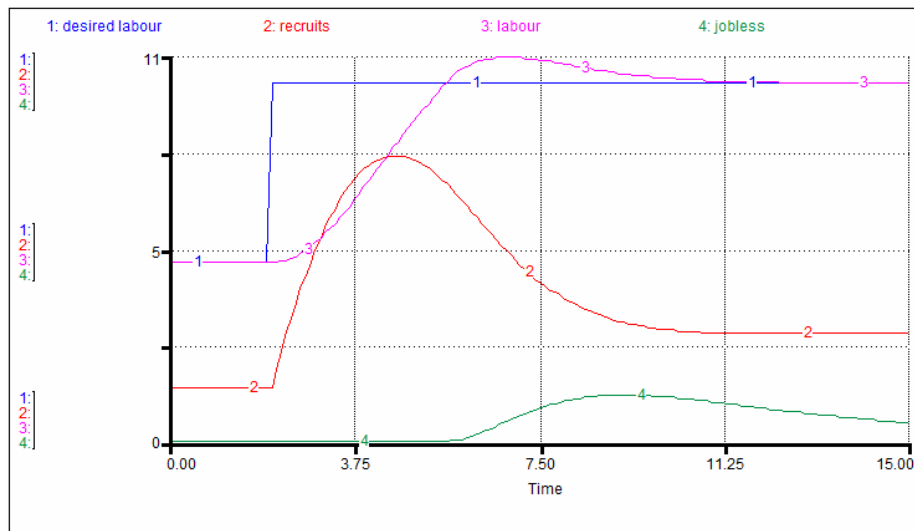
$$\text{recruitment_start_rate} = \max(0, \text{labour_gap}/\text{time_to_recruit} + \text{expected_labour_quit_rate})$$

The models implicit assumption is that recruits do not contribute to construction. As recruits are at schools, preparing for going into the industry this is true. However, when taking apprenticeships in construction, they will contribute to production, though at the cost of lower productivity for skilled workers who are instructing apprentices. The simple approach of using a number of years for training time is perhaps a justifiable one, if not quite correct for describing the details for how recruits contribute.

The behaviour of the whole capacity sub-model is illustrated in Figure 23.

Figure 23: The isolated effect of a change in desired

A change from 10 to 20 units of desired capacity does not immediately induce effects on construction capacity, the capacity builds up gradually. To arrive at the full effect takes five time units, and in this model there is an overshoot – the capacity builds up to more than the desired capacity and is accordingly adjusted down again. The corresponding changes in the number of *recruits*, *labour* and *jobless* are shown in Figure 24.

Figure 24: The isolated effect of an increase in desired labour on recruits, labour and jobless.

As indicated in the figure, a step increase in *desired_capacity* causes the *desired_labour* to increase. The *recruitment_start_rate* increases and exceeds the equilibrium level, in which the start rate shall equal *labour_attrition_rate*. The number of *recruits* increases.

Consequently the *labour* stock increases, however with a delay in relation to the stock of *recruits*. Therefore, as the labour stock increases and surpass its desired level, a number of workers become abundant. Consequently the number of *jobless* increases from its initial value. There is a positive *labour_gap* until *labour* equals the desired level, and in the equation for the *recruitment_start_rate*, the recruitment beyond the quit rate is positive as long as the *labour_gap* is positive. All stocks remain non-negative for all conceivable parameter values and inputs, even for a negative *desired_labour*.

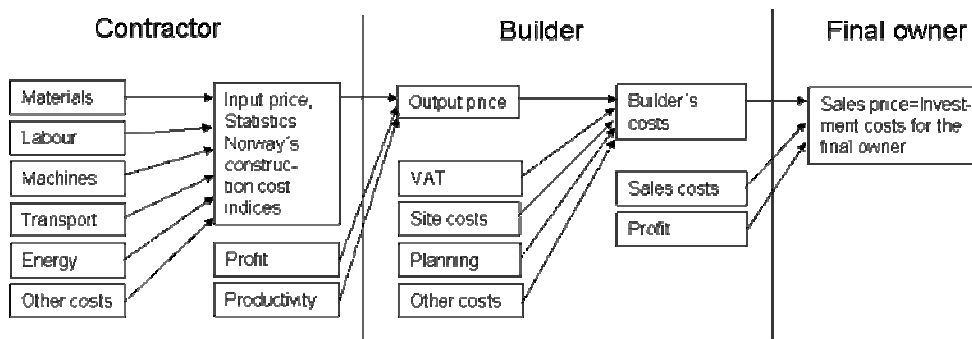
7.3 FORMATION OF COSTS AND PRICES

7.3.1 CONSTRUCTION COSTS

Housing construction costs in this context is the total cost of building houses, including a “normal” profit for the real estate developer for a certain physical output. Typically, the measure of output normally is represented by housing area, though other qualities may vary considerably, for instance materials and workmanship, various housing facilities and location.

Figure 25 illustrates the cost elements for new housing construction. The main categories are the contractors’ costs, the builders’ costs and the final owners’ investment cost when buying new housing. The contractors’ costs consist of, inter alia, material and labour costs, machinery and transport cost and energy costs. These cost elements will tend to vary, depending on pressure in the economy arising from the activity level.

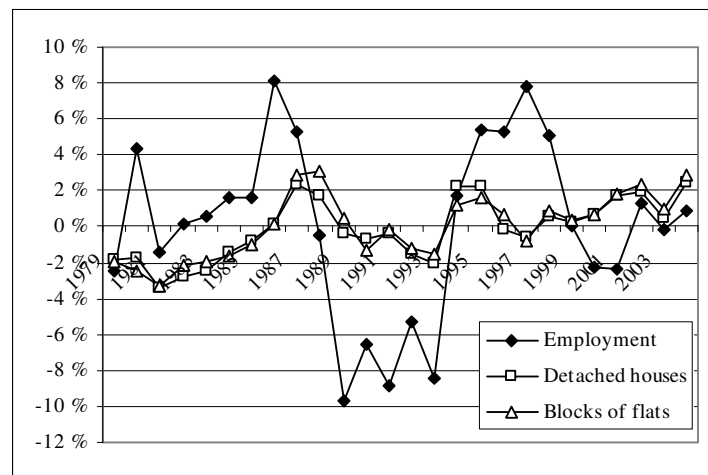
Figure 25: Cost elements for new housing construction. (Source: Ministry of Local Government and Regional Development (2004))



The Norwegian Broadcasting Corporation (NRK (2007)) reported a 40 per cent price increase in wood-based construction materials over from 2006 to 2007, among other things because of high housing construction activity nationally and internationally and consequently a scarcity of materials. Prices on construction materials are therefore bid up temporarily until supply becomes sufficient.

The connection between activity level and prices is not quite clear. An attempt to estimate the relationship for instance between the annual change in employment in construction, and the annual change in real (deflated) construction costs for detached houses and blocks of flats did not give significant results¹⁵. Figure 26 indicates annual changes in the three variables. “Visually” it seems to be a correlation between growth in employment and the growth in construction costs in Figure 26.

Figure 26: Annual change in per cent in employment in construction industry, construction cost index for detached houses and blocks of flats. Construction cost indices are deflated by the consumer price index. Norway 1978-2004. (Source: Statistics Norway)



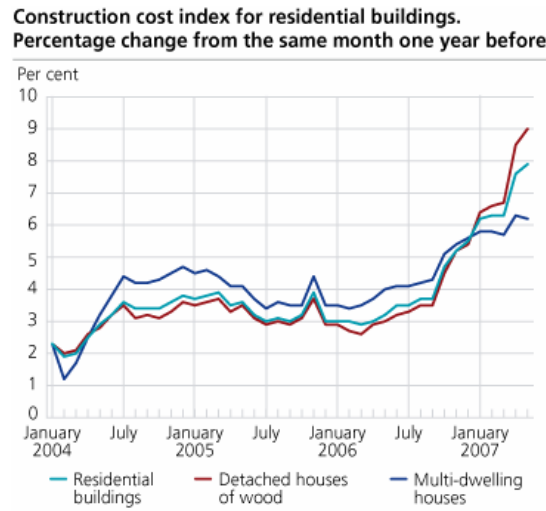
¹⁵ The relation (annual change in construction costs) = $a \times$ employment, i.e., employment in construction industries, has been estimated by means of a regression, ordinary least squares. The result for the so-called t-value for the estimated coefficient a was 1.4 for detached houses, based on the numbers from figure 16, which is less than the “required” value for significance, which is at least 1.9. For the price change for blocks of flats, the t-value coefficient was one. The values of the coefficient a was 0.099 for detached houses, and 0.075 for blocks of flats.

The test was performed on national data, and for this reason the effect of demand for materials internationally may distort the result, as well as possibly other important variables are left out. Furthermore, Statistics Norway’s statistics on employment in the construction industry includes the whole industry, not only housing construction.

Labour wages will probably also tend to be bid up as long as there is a scarcity of that resource, however, recently there has been a considerable migration of qualified workers from abroad, particularly from the former East Block economies. This has probably reduced the effect of pressure on wages.

Recent development in contractors' construction costs is illustrated in Figure 27. Referring to Figure 25, the construction cost index in Figure 26 includes only contractors' costs.

Figure 27: Construction cost index for housing construction (Source: Statistics Norway)

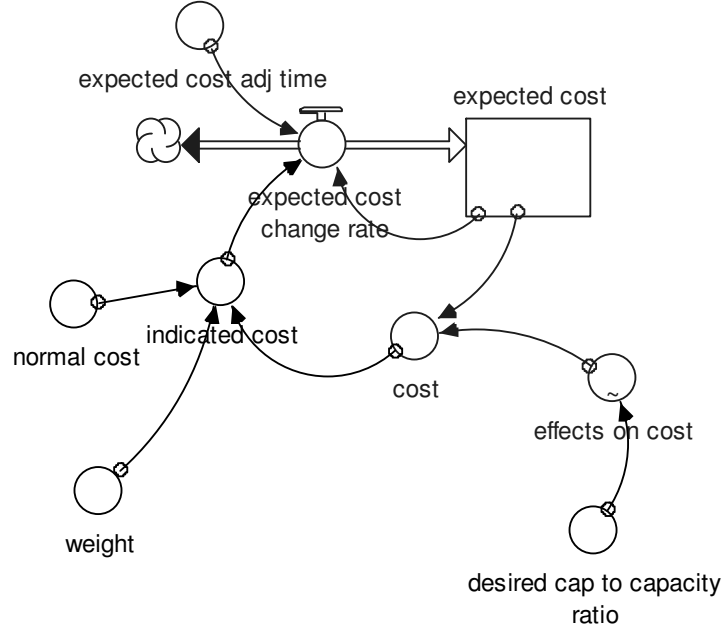


In addition to the costs of construction, the costs of ground for construction are included in the total construction costs, including “normal” profits for all the participators in the delivery chain needed in order to deliver final housing. The terms “cost” and “expected cost” in the stock-flow diagrams are anticipated to include all these elements.

Statistics Norway's figures for housing prices and construction costs indicate that the relation between the annual change rate for prices and costs are in the range of 0.14, i.e., when prices increase by ten per cent, the costs increase by 1.4 per cent with fair statistical test results. However, these data time series include a relative short time period from mid 1980-ies to 2007. Tentatively, the relation between desired and actual construction capacity will be used as input to *effects_on_cost*. Details are presented in the following.

Represented in a stock-flow diagram, the cost of construction and expected cost are related to each other as shown in Figure 28.

Figure 28: Relation between cost and expected cost in construction



Real estate developers, contractors and planners will respond according to the *expected* cost of construction. The expected costs are delayed related to real costs, among other things because it takes time to process new cost data and to inform decision makers about these data. Costs depend on for instance material costs and wages. Both material costs and wages will depend on the pressure in the industry as indicated in the example above – and wages; not easily foreseeable. Consequently, actors on the housing supply side will have a delayed response to price variations on production input. The average delay time is represented by the cost expectations adjustment time. Such effects are represented in *effects_on_cost* in the diagram in Figure 28, and the *effect_on_cost* is assumed to vary around unity. The equations in the construction cost sub-model in Figure 28 are defined as the following:

$$\text{effects_on_cost} = f(\text{desired_cap_to_capacity_ratio}) = f(\text{desired_capacity}/\text{construction_capacity})$$

$$\text{cost} = \text{expected_cost} * \text{effects_on_cost}$$

$$\text{indicated_cost} = \text{cost} * (1 - \text{weight}) + \text{normal_cost} * \text{weight}, \quad 0 < \text{weight} < 1$$

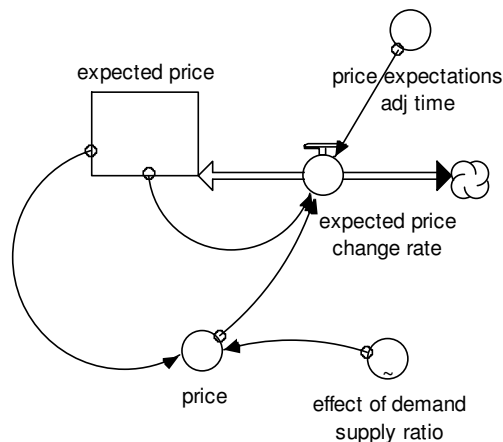
$$\text{expected_cost_change_rate} = (\text{indicated_cost} - \text{expected_cost}) / \text{cost_expectations_adj_time}$$

The *expected_cost_change_rate* in the diagram is a flow, which adjusts *expected_cost* according to variations in actual cost (*indicated_cost*), delayed with the delay time *expected_cost_change_rate*. The *indicated_cost* is a function of cost and normal cost. This function cares for adjusting the *indicated_cost* towards *normal_cost* when the model approaches equilibrium, a so-called anchoring and adjustment process. *Cost* and *expected_cost* are non-negative for any viable input.

7.3.2 HOUSING PRICES

Actual price and price expectation can be modelled similar to the cost and cost expectations' formation. Price expectation is an aggregate stock of information based on individuals' price expectations. The variable *price* is the result of actual sales. The sales process that results in prices for the actual sales depends on a variety of factors. The most important is probably buyers' interest in and the awareness of the sales object, which will depend on the expectations to so-called "fundamentals", such as expectations regarding income, unemployment rate, interest rates etc. Variations in the "fundamentals" will imply variations in how keen people will be in the consideration of buying a new home. If for instance the "fundamentals" are increasingly prosperous, the number of potential buyers in the housing market will increase. Many bidders in a sales process will tend to raise the price of housing, while, on the other hand, few bidders will tend keep price low. Similar to the creation of cost expectations, the price expectations may be equally formulated. Figure 29 indicates the structure:

Figure 29: Relation between price and expected price



Both sellers and buyers will react in relation to the *expected* price of housing. Prices will inevitably depend highly on the availability of housing related to the demand for housing. The *demand_supply_ratio* is an important measure for the relative availability of housing and housing prices– in the longer term probably the most significant (however, “noise” from short term variations in supply and demand may have lasting effects as well). Such effects are represented in *effect_of_demand_supply_ratio* in the diagram in Figure 29, and the “normalised” value of *effect_of_demand_supply_ratio* is unity, i.e., the value that leads to equilibrium. The equations in the sub-model in Figure 29 are defined as the following:

```

effect_of_demand_supply_ratio = f[housing_demand / housing_supply]

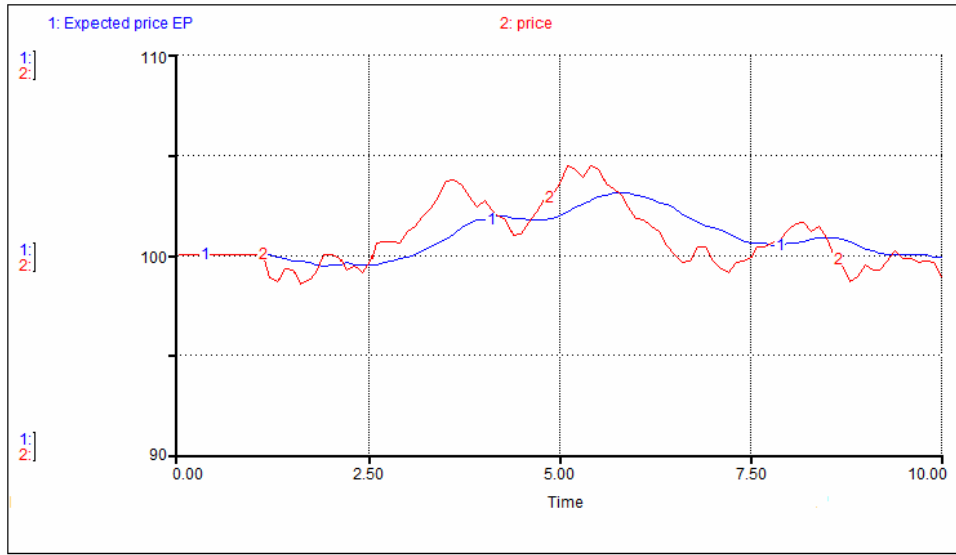
price = expected_price * effect_of_demand_supply_ratio

expected_price_change_rate = (price-expected_price) / price_expectations_adj_time

```

The *effect_of_demand_supply_ratio* will vary around unity. When either demand or supply fluctuates, *effect_of_demand_supply_ratio* will fluctuate. Since the price equals *expected_price* times *effect_of_demand_supply_ratio*, the price will vary with the ratio. This, in turn, will affect the flow that adjusts *expected_price*; the *price_expectations_change_rate* in the figure, which equals *price* minus *expected_price*, a gap which adjusts *expected_price* according to variations in actual price, delayed with the adjustment time. The flow is negative when *expected_price* is greater than *price*, positive if *expected_price* is less than *price*, adjusting the *expected_price* up or down according to the discrepancy compared to the current price. Figure 30 indicates the effect of a “noisy” price on *expected_price*. While *price* varies considerably, the *expected_price* has a smoother shape and retarded reaction to variations in the *price*.

Figure 30: The effect of variations in the price on expected price. Adjustment time is one time unit



The variables *price* and *expected_price* are non-negative for any viable input value; this is also what we can observe for economic commodities in the real world. A question is whether there should have been different price expectations for professionals such as real estate developers and brokers, compared to ordinary people who decide on buying a new home.

7.4 THE DEMAND FUNCTION

Demand will depend on a variety of conditions. Price and interest rates are considered to be among the most important. However, repayments on loans, property taxes, maintenance costs, electricity, etc., are expenditures¹⁶ that will have an effect on demand. Peoples' expectations regarding their private economy count as well, and the unemployment rate has been considered to have an effect through the *expectations* that unemployment may create for peoples' consideration of their economic prosperity.

A simplified approach will be used in the basic model runs - aggregate housing demand is determined by housing prices, not housing expenditures. This is justifiable because housing

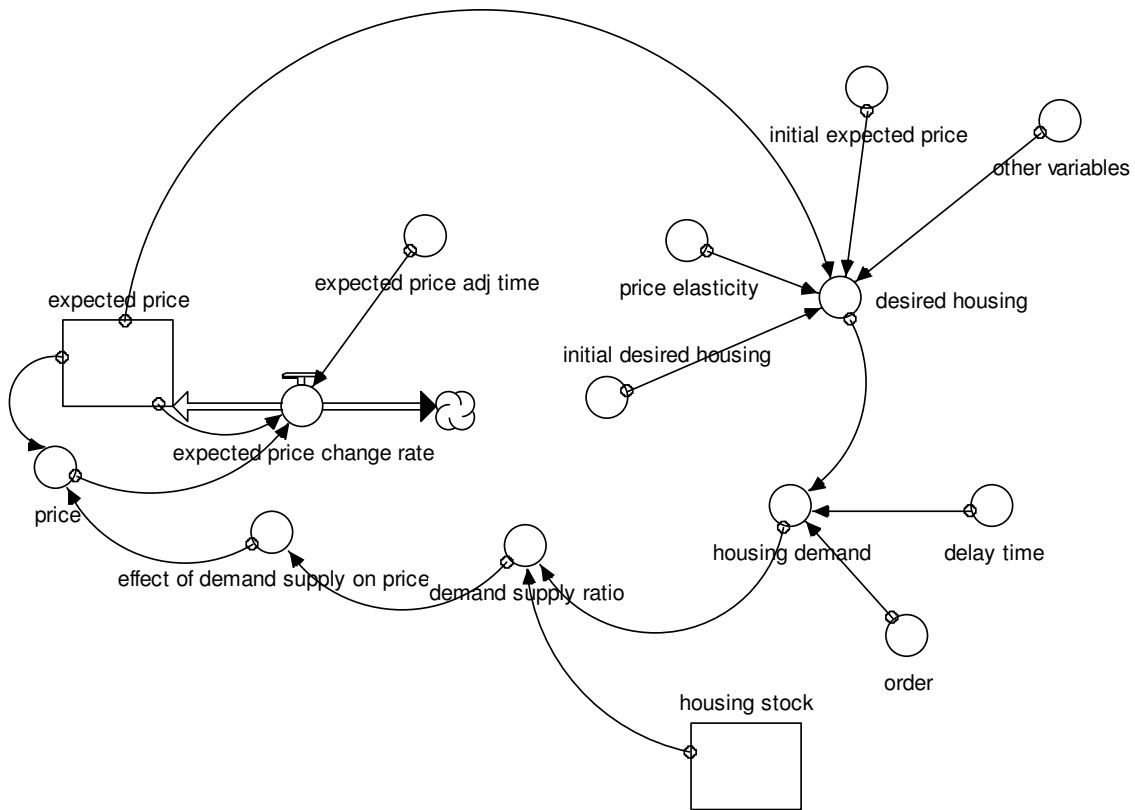
¹⁶ The distinction between housing *expenditures* and housing *costs* lies in the exclusion of repayments on loans for housing costs. Among economists, repayments are considered as savings. However, housing expectations regarding current and future expenditures are probably important for households when they are deciding on buying a home.

prices have varied much, while other housing expenditure components have varied much less, and not necessarily correlated with housing price variations.

Desired housing is defined as follows, in terms of a Cobb-Douglas demand function¹⁷:

$$\text{(desired_housing)} = \text{initial_desired_housing} * ((\text{expected_price} / \text{initial_expected_price})^{\text{price_elasticity}}) * \text{(other_variables)}$$

Figure 31: The primary elements of the desired housing and housing demand function related to price and supply

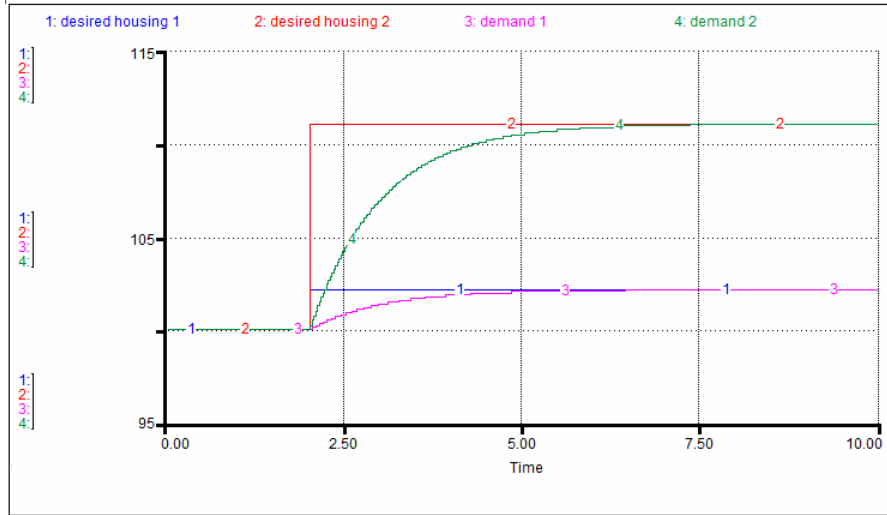


The *expected_price* affects *desired_housing*, which in turn has an effect on *housing_demand*. If for instance *expected_price* declines, *desired_housing* will increase, and consequently also *housing_demand*. The *price_elasticity* determines the strength of response in *desired_housing* and *housing_demand* - the higher the price elasticity's absolute value, the greater the change in *desired_housing* and *housing_demand*. Figure 32 shows the effect of a

¹⁷ See Appendix 1

decline in price on desired housing for a small and a high absolute value of the price elasticity. Price elasticity is -1 for the upper curves, and -0.2 for the lower curves

Figure 32: Illustration of the isolated effect on desired housing and housing demand for a price decline.

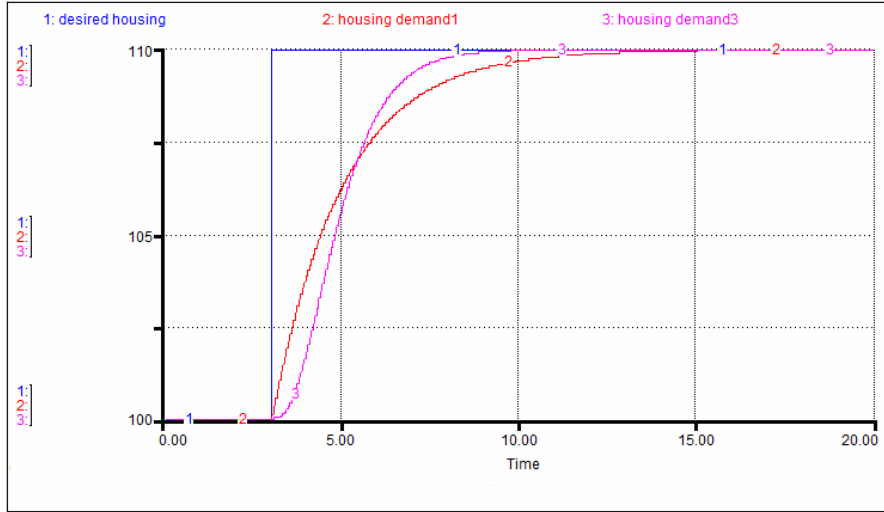


The equation for *housing_demand* is the following:

$$\text{housing_demand} = \text{smoothN}(\text{desired_housing}, \text{delay_time}, \text{order})$$

Even if *desired_housing* changes, there will not immediately be a corresponding change in *housing_demand*. In the real world people will need time to prepare for the idea of moving to another home. Furthermore, decisions and actions must be taken regarding financing; actions must be taken in order to prepare for sale, purchase, plans for moving etc. For these reasons, changes in desired housing will just gradually result in changes in demand. The *housing_demand* structure mimics this behaviour by means of the “smoothN” formulation, which is a built-in function in system dynamics simulation software, and is just another way to present an Nth-order exponential smoothing process, which consists of a series of N flow inter-linked stocks. The isolated effect of the smoothing process is illustrated in Figure 33.

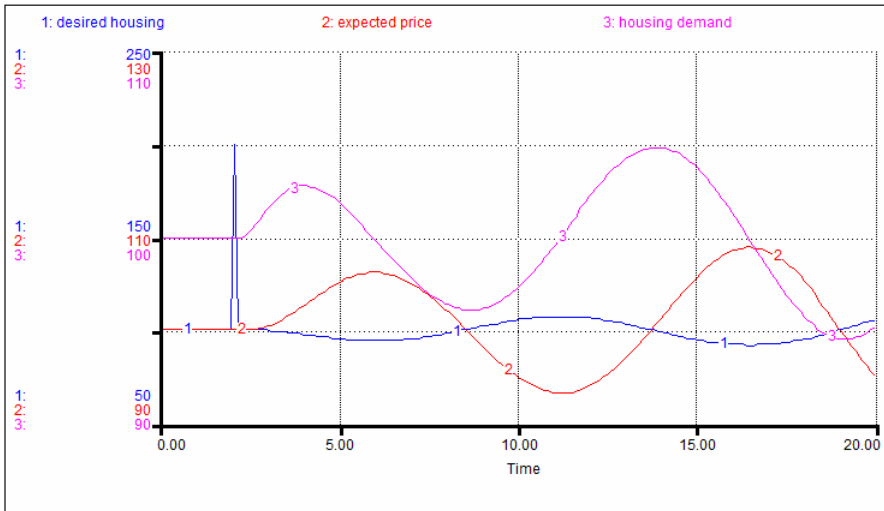
Figure 33: Illustration of the isolated effect of smoothN function with a ten per cent step-up in desired housing, first- and third-order smoothing



In the more extended simulations the model shall be extended with respect to the input to *desired_housing* by using different variables in the one that is named *other_variables*.

Figure 32 and Figure 33 show the *isolated* effects of a price change and smooth effects. The structure in Figure 31 is a balancing structure, and it has sustained oscillations if housing demand represents a considerable delay in relation to desired housing. The

Figure 34: Oscillatory behaviour of the structure presented in Figure 31



7.5 COMPLETION OF THE MARKET LOOPS

The elements of the supply chain have been discussed in the section “The housing planning, construction and supply chain”, and they are illustrated in Figure 17. The formation of costs “Construction costs”, illustrated in Figure 28. Price formation is assumed to be similar to the cost formation, except for the inclusion of *normal_cost* in the cost loop. The description of price and expected price formation is in the section 7.3.2 “Housing prices”, illustrated in Figure 29. In Figure 35, the elements from the previous discussion are linked together in a simplified outline of the “complete” housing market. The *desired_additions* from Figure 17 has been left out. The elements not defined previously are the following:

```
demand_supply_ratio = (housing_demand)/(housing_stock)
effect_of_demand_supply_ratio = f[demand_supply_ratio]
```

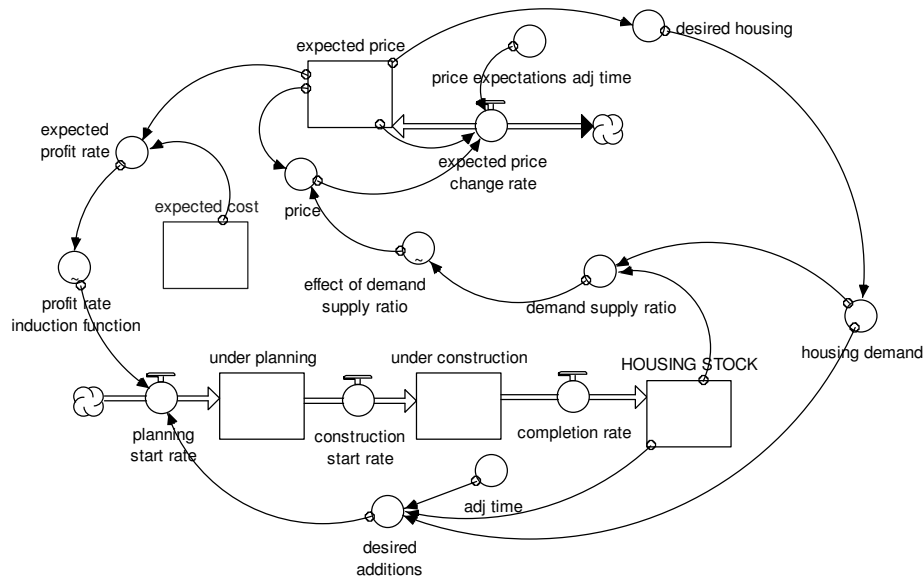
As mentioned previously, the ratio between expected price and expected cost is a prerequisite for construction to take place. The *expected_profit_rate* as previously defined will determine the *planning_start_rate* in Figure 17. If the *planning_start_rate* is positive, the housing supply will increase through the housing supply chain in Figure 35, and reduce the *demand_supply_ratio* shown in the figure. The *demand_supply_ratio* is defined as the following:

If housing prices exceed construction costs there will be stronger incentives for constructing new housing in order to earn money, compared to a situation with prices lower than costs. The higher the profit compared to cost is expected to be, the stronger the incentives will be for new housing construction. The expected profitability (not exactly equal to Tobin’s Q, but functionally similar), is defined as follows:

```
expected_profit_rate = (price-cost)/cost
```

If profitability is greater than 0, there is a positive profit and construction will take place. The higher the profitability, the higher the construction rate. At value 0, construction will balance economically, price equals cost. At values less than 0, we may expect that construction declines for declining values of the *expected_profit_rate*. However, at values less than zero we may expect that construction still will take place, however for other reasons than *current* profitability.

Figure 35: General outline of the housing market supply and demand¹⁸



In the section 7.1 “The supply chain” two major loops, one balancing and one reinforcing, are described more in detail.

7.6 MODEL BASE RUN

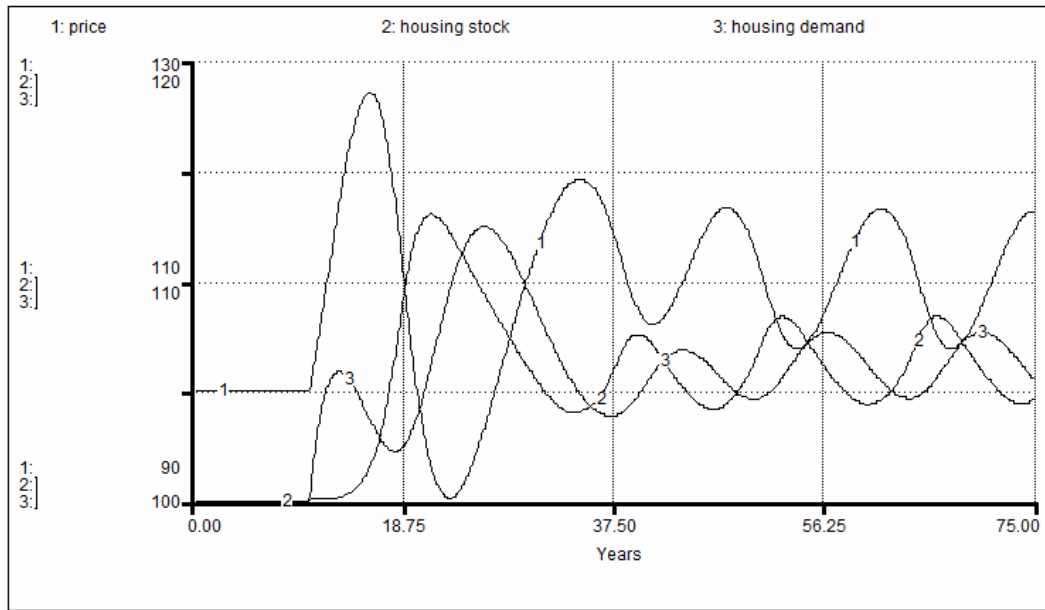
In the following, the model results from a *base run* are presented. These first results are based on the assumption that costs per unit are fixed, and that there is no management of the supply line. This will be modified later. Supply line management has been described in the section “The supply chain”, and the structure will be employed in the section 8.9.15 “Adding management to the supply chain” in order to see how the refined model’s behaviour will change compared to the base model. This extension will also be discussed in section 9.1 “Managing the supply chain”.

The model has been initialised in equilibrium, i.e., a model run in order to monitor that all stocks remain constant. Initialising in equilibrium secures that there are no unintended

¹⁸ Some details are left out. Complete outline of the supply chain is presented in Figure 17 and in Appendix 2A.

“leakages”. The model’s stocks remain constant; and the inflows and outflows are equal, and all stocks remain at a constant level. Then, a step increase in *desired_housing* is introduced (year 10). The model equations, graph functions and constants are as presented in Appendix 2. Figure 36 shows the development in *price*, *housing_demand* and *housing_stock*. The simulation gives sustained cycles with a cycle length at about 16 years when the system stabilises after year 50, indicating limit cycles. This is much in line with the indications from Figure 9, where the cycle wavelengths are found to be between 6 and 16 years.

Figure 36: The effect of a ten per cent step increase in *desired_housing* on price, housing stock and housing demand. Effects of costs and supply line management not in effect.



The step increase in *desired_housing* causes a delayed increase in *housing_demand*, which in turn causes an increase in *the demand_supply_ratio*. This has an effect on price and profitability.

The increase in demand causes housing prices to increase. For this reason profitability of new housing construction increases, and new housing construction will take place. This, in turn, reduces the housing shortfall, and prices consequently decline. Profitability turns down, and for this reason also housing construction. Because housing removals depletes the housing stock, i.e., supply, the prices again will increase, and construction takes place again – the demand, supply and prices oscillate, as well as labour, recruitment and unemployment. The reason for this is that there are balancing loops (three major balancing loops in the market

sub-model and one in the supply line sub-model) with different delays, and corrections between the different loops are not synchronous.

Figure 37 indicates the development over time for labour and jobless in the base run.

Figure 37: The effect of a ten per cent step increase for labour and jobless. Effect from costs are not yet introduced.

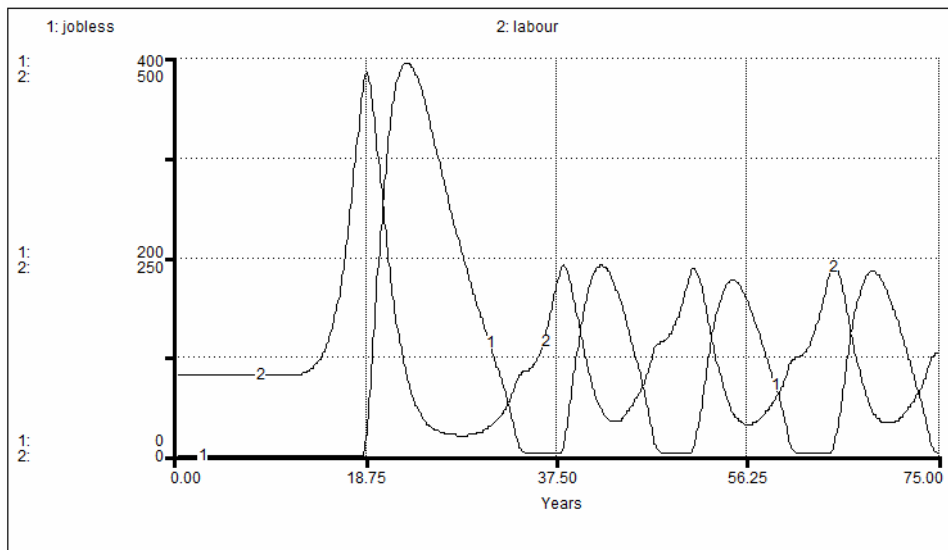


Figure 37 shows the development in the number of workers and jobless. According to construction activity and the resulting changes in the housing stock as indicated in Figure 36, there are also oscillations both for workers and jobless. The irregular “dip” in the labour curve when it grows is a result of the draining of the pool of jobless before recruitment of additional labour fully takes place.

A question is whether it is realistic that the labour stock declines almost to zero from a high level at above 200 and a “normal” level at 100 (initial). As described previously, the stock of workers in the housing construction industry declined from 47,000 to 15,000 over six years after 1987. This dramatic drop occurred when there still was a growth in population.

The model base run has been carried out on a completely closed structure (except, of course, from the exogenous step increase in demand). Demand, supply and capacity are mutually dependent on each other. If this structure reflects the real world sufficiently, the base model indicates that the structure itself is capable to create sustained oscillations.

According to what we can observe from historical data, the model creates fluctuations much in line with observations with respect to wavelengths.

8 MODEL TESTING AND VALIDATION

8.1 INTRODUCTION

Model validation is described as a continuous practice throughout the whole model building process. “Clients”¹⁹ and modellers build confidence in the model as work progresses (Sterman (2000)), but, a model can never be validated in the sense that it is *verified* (according to Sterman “all models are wrong”). In the current work literature reviews, news and archival material about housing demand and construction, experts’ opinions, etc., have been bases for developing experience, in parallel with the modelling work. Additionally, two semi-structured interviews with real estate developers have been performed in order to get a better understanding of the housing market and to establish values to certain parameters (Appendix 3).

A series of tests are recommended for building confidence in system dynamics models. Model testing methods are described for instance in Sterman (2000). These tests include boundary adequacy test, structure assessment test, dimensional consistency and parameter evaluation tests, extreme conditions test, integration error test, behaviour reproduction test, behaviour anomaly test²⁰, family member test, surprise behaviour test, sensitivity analysis and system improvement. In the following these tests will be carried out or commented in relation to the model.

¹⁹ Refers to principals or employers.

²⁰ “Loop knockout” analyses; this has been part of the whole modelling process and will not be commented in the following.

8.2 BOUNDARY ADEQUACY TEST

This test is used for considering whether the model is suitable for its purpose or not, and to test for additional structures, alternatively to relax boundaries in order to inspect whether changes in model boundaries change the behaviour of the changed model structure.

The background for the current work is to illuminate the possible loss of welfare; for buyers and sellers of housing related to the uncertainty that cycles give for people's unintended losses and possible gains, and for those who choose a career in the housing construction industry. The purpose for the current study is to examine whether the system for housing supply and demand induces cycles, in this respect cycles that makes predictability poor for groups of people who supposedly in general are risk adverse to investments in necessities, such as housing. Furthermore, the aim is to see how the interaction between the job market related to housing construction and the housing market itself gives uncertain careers in the housing construction industry, which is unfavourable both for home buyers (housing quality) and for workers in the industry.

The purpose with this test is to control that the principal variables that shall explain the dynamic hypothesis are endogenous. Referring to the overview in the model boundary chart in the section "Model overview", and the two sub-models market and capacity in Figure 15 and Figure 16, the illustration in Figure 38 shows that the base run model is completely closed for all the principal variables – these are endogenous. Some details related to the stock-flow model are left out.

Extending the model, for instance by including scarce planning resources (but with a longer time for education) in the same manner as for labour does not seem to change model behaviour much. However, the cycles become somewhat less frequent. One reason for this is that the time for training was set to a considerably longer time for planners than for labour.

The price elasticity value will vary with price. As price move towards zero, the price elasticity will also move towards zero. In practice, changing the model with variable price elasticity does not change the behaviour of the model significantly within the ranges of the model runs. Therefore the price elasticity has been set to a fixed value.

Other constants in the model, for instance time to plan, average lifetime for buildings, and firing adjustment time, might be variable in the real world. These are not tested as variables in the boundary adequacy test.

Changing the model by making housing planning and construction a managed chain, i.e., by using information concerning quantities in the supply chain to restrict new start-ups, eliminates cycles rapidly. This will be discussed further in the testing of added structure and in the chapter on policy implications.

8.3 STRUCTURE ASSESSMENT TESTS

This test raises the question whether the model is in line with relevant description of the system or not, and whether the model's aggregation level is appropriate. Furthermore the test shall reveal whether the model comply with physical laws, for instance that stocks are non-negative, and that decision rules are in line with actors' behaviour in the real world. The procedure recommendations for this test are, inter alia, to inspect by means of causal loop diagrams, stock and flow structure as well as examining the equations. Interviews and experts' opinions are recommended.

There are outflows from the model's stocks. For this reason these may in *principle* become negative, which for instance for the *housing_stock*, *labour* and *jobless* in the reality is impossible. The model details are elaborated in the chapter "Housing market model", in which the behaviour of each part of the model has been considered. The outflows either have

first order controls that prevent the outflows to deplete stocks to negative values, or, other control procedures that leave stocks non-negative.

Literature reviews and experts' opinions have been used in order to develop the model, and to see to it that the terms and their definitions in the model have real-life counterparts.

8.4 DIMENSIONAL CONSISTENCY AND PARAMETER EVALUATION

The dimensional consistency test requires that units in the model are consistent in the equations. This can be used by means of the software packages for system dynamics modelling, alternatively by examination of the equations. Parameters without a real-life meaning shall not be used, such as scaling factors to "improve" model output. In Appendix 2 the model equations are presented, including dimensional definitions. Thus; the dimensional consistency test is completed there.

Parameter values are required to be consistent with relevant descriptive and numerical knowledge of the system. The parameters might be assessed through statistical methods or judgmental methods based on interviews, archival materials, etc. The current model parameters have, to a high extent, been based on experiences and judgements built through the model elaboration by means of a broad literature review, searches in statistics databases, and experts' opinions.

8.5 Extreme Condition Tests

Models should be robust in extreme conditions. In the presentation of the sub-models, the sub-models' behaviour has been commented as to values for extreme inputs, and whether the values are consistent or not. The final test is to include extreme values and conditions for the whole model. This may reveal flaws that not necessarily can be observed by direct inspection of equations in sub-models. Candidates for extreme values in spot tests are for instance construction capacity, price, average lifetime of buildings, and costs of construction. Here, testing for capacity and price has been performed. The results are presented in the next two sections.

8.5.1 CAPACITY DROPS TO ZERO

If capacity drops to zero, the expected value for housing stock should drop towards zero, and prices will increase. For doing this test, the model has to be reformulated because some of the variables are defined with construction capacity (CC) in the denominator for input to the cost function and to the completion rate. Furthermore CC is part of the input to the planning start rate. Decoupling CC from the planning start rate may be made by letting desired additions and the let the profit initiation function be the only arguments in planning start rate. Decoupling CC from the completion rate may be carried out by using a MIN function for the completion rate, i.e.,

```
completion_rate = MIN(construction_capacity, under_planning/normal_time_to_construct)
```

that *functionally* is a counterpart to the original formulation, though less sophisticated. CC as denominator in input to the cost function is eliminated just by setting expected cost to 100 and decouple connections between CC and cost. Cutting CC in the MIN function above implies, as suggested, prices to increase exponentially, and housing stock to decrease. The housing under planning and construction increases in general. All stocks remain non-negative.

This test indicates that there should be outflows both from *under_planning* and *under_construction*; because it is a more realistic suggestion that projects will be cancelled²² if they are difficult to complete, for instance if the market conditions are considered unfavourable. However, in “normal” ranges project withdrawals may be kept out of consideration.

The price increases to infinity. That is not realistic. However, this is a result of the assumption that the price elasticity is invariant to price. During the modelling process, and, under “normal” ranges, variable versus constant price elasticity did not give significant differences in results of model runs. Another comment to the exponentially rising prices is

²² One real estate developer suggested that in average about ten per cent of the planned projects were cancelled

that budget control mechanisms, such as realistic budget shares²³, and a limited consumption budget, are left out from the modelling. Variable price elasticity control, or budget share control, are to some extent, alternative approaches.

8.5.2 EXTREME HOUSING PRICES OR COSTS DROP TOWARDS ZERO

An extremely high step in the expected price change rate implies, of course, that price increases to extremely high values. Consequently demand declines towards zero. All stocks, except price and cost, the latter ruled by the normal cost in this run, decline to zero, but are all remain non-negative.

If costs drop towards zero, the profitability will increase, even for lower prices. Prices turn down, while, on the other hand, housing stock will increase. All stocks remain non-negative.

8.6 INTEGRATION ERROR TESTS

System dynamics software uses stepwise iterative integration. For this reason model runs may make erroneous results, and, the longer the time horizon, the greater the deviation from the correct value. It is recommended that a test should be made by observing if a change in the time step and the integration method affect the results. Integration methods include the Runge-Kutta and the Euler method. It appears that Euler's method performs badly for the time step test, which is to cut the time step to the half. With Euler's method this resulted in considerable deviations in the results. For the Runge-Kutta method, on the other hand, cutting time step resulted in negligible changes. The Stella software handbooks recommend the use of Runge-Kutta when for instance MAX functions are employed. MAX functions are employed in the model.

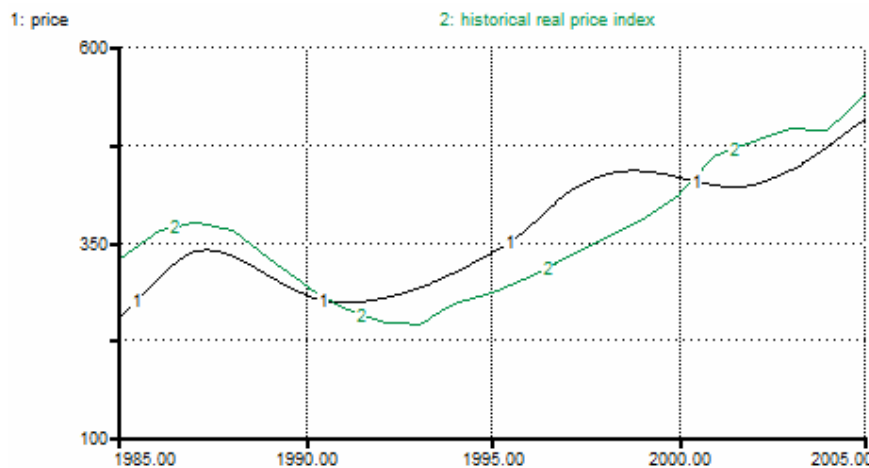
²³ Budget share for housing varies, depending, among other things, on interest rates and time to adjust in the range 20 to 35, and an average a little more than 20 per cent

8.7 BEHAVIOUR REPRODUCTION TESTS

In the behaviour reproduction test the models results are compared to historical data. Data for instance for prices before the 1980-ies are less available, except for the result from Qvigstad (2004), in which prices for the larger cities are used. In the current test, data from NEF²⁴ are applied. Data from this source are from 1985 onwards. A lot of fin-tuning of parameters was necessary to achieve model results to fit to historical data. The costs were set to a fixed value of 100. Supply line management is not in effect. The time series and constants are presented in Appendix 2B. (Some of the time series are from 1950, that is a reminiscence from previous test runs.)

In Figure 39 shows the results from the model with adjusted parameter values and exogenous input for population, consumption (deflated), and real interest rates after taxes.

Figure 39: Model run 1970-2005, displayed from 1985, with exogenous input for historical interest rates, consumption and population growth



Values of constants and table functions have to be adjusted stepwise and “simultaneously” in order to calibrate the model to fit the historical data. There is a potential for better calibration than the one that gives the results in Figure 39, however, a lot of fine-tuning is needed.

Using least square regression for annual change in price “depending on” annual change in historical price gives results as in

²⁴ NEF; Norges eiendomsmeglerforbund (“The Norwegian Real Estate Broker Association”)

Table 1: Statistics for annual price change rate compared to annual historical price change rates.

Model contains no constant

Dependent variable: PRICE N: 21 Multiple R: 0.697 Squared multiple R: 0.486

Adjusted squared multiple R: 0.486 Standard error of estimate: 0.058

Effect	Coefficient	Std Error	Std Coef	Tolerance	t
HISTORICAL PRICE	0.695	0.16	0.697	1	4.35

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	0.064	1	0.064	18.923	0
Residual	0.067	20	0.003		

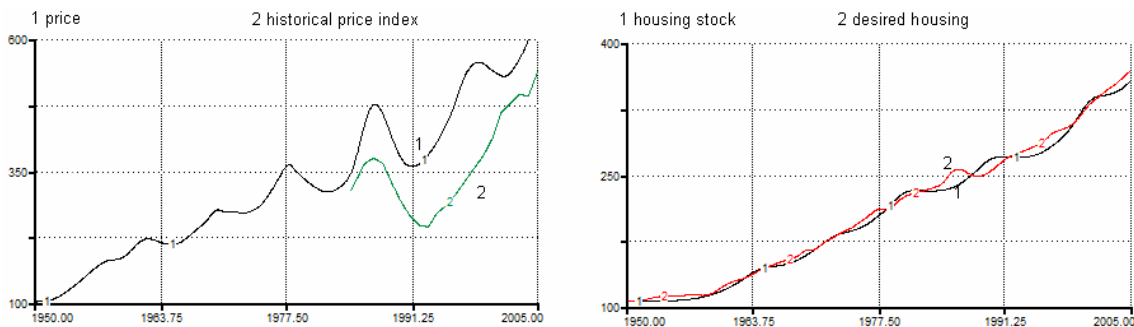
Durbin-Watson D Statistic 0.719

First Order Autocorrelation 0.626

Visual inspection of Figure 39 indicates that the model reproduces historical data fairly well. The test results in also indicate that there is a correlation between model results and historical figures, with fairly good t-value and F-ratio.

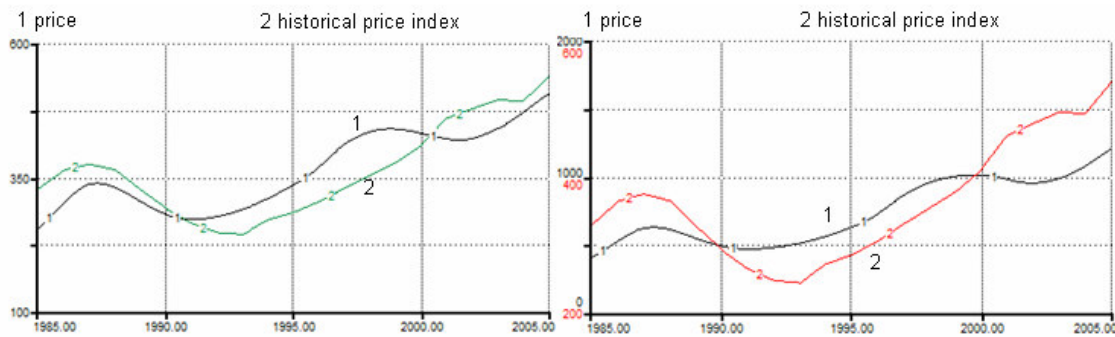
Figure 40 indicates the simulation results for the period 1950 to 2005 for prices, housing stock and desired housing, and for historical prices.

Figure 40: Simulation results for price compared to historical real price (left curves), and simulation results for housing stock and desired housing based on exogenous input for consumption, population and interest rates



In the following, the model will be “degraded” with respect to the influence of interest rates. In figure the interest rate is set to a constant “normal” value (5 per cent per year). Figure shows two runs, one with historical interest rates identical with the curves in figure 38, the second constant “normal” interest rates.

Figure 41: Model runs as in fig 38 to the left (historical interest rate in effect) and constant interest rate to the left.



The scales change in the new run (to the right), however, the shape of the figure indicates that the effect of interest rates over the period considered does not seem to be a significant driver for *cycles* (re-calibration of the model is needed in order to eliminate the scale deviation). Increasing the *effect_of_interest_rate* further than for the model run results presented in Figure 41 does not make much change to the *shape* of the price curve.

8.8 FAMILY MEMBER TESTS

The family member test requires that the model generates the behaviour of other cases of the same class of system type. Meadows (1970) has analysed hog cycles, and found that his model reproduced the behaviour of the cycles found in the real world. He also tested on cattle and chicken production and found similar behaviour. His approach was the Cobweb model modified with a system dynamics approach. The current housing model is in principle a Cobweb model, with the key indicators supply and demand, profitability and considerable time delays, and the variables fluctuate.

The analyses made by Kummerow (1999) are performed for cycles for office buildings, and he states under similar conditions regarding time delays that the office building market fluctuates. Zhang (2001) has based a system dynamics analysis on the work of DiPasquale and Wheaton (1996), reproducing cycles that can be observed from the real world when price expectations were based on the assumption of “myopic backward looking expectations”. The current “Norwegian” housing model has similar behaviour as the models referred to above.

8.9 SENSITIVITY ANALYSES

Sensitivity analyses include numerical analyses, sensitivity to various boundary assumptions, structure left out or included, and policy sensitivity. Sensitivity to various boundary assumptions is, to some extent, dealt with in the section about boundary adequacy tests. Some of the results from the sensitivity analyses will be discussed further in chapter 9 “Policy considerations”.

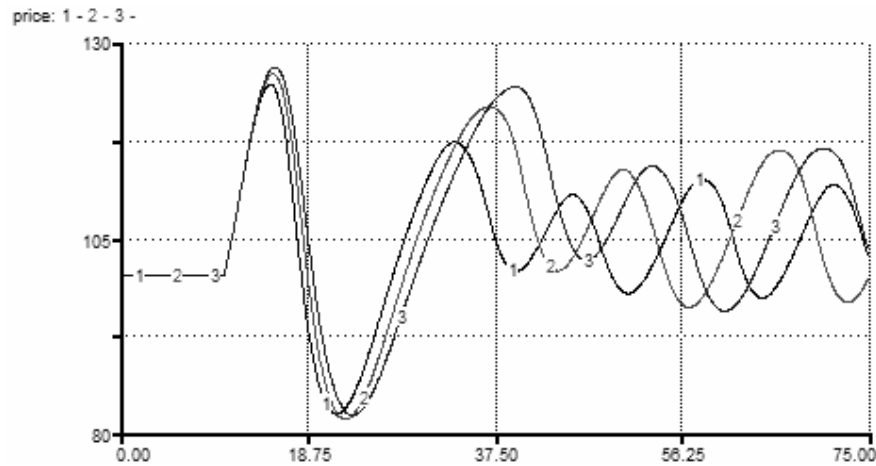
Key variables according to the problem raised in the current work are price, labour and jobless. For the first sensitivity run in the following, price, labour and jobless for a ten per cent step increase in demand will be observed. Since the purpose of this analysis is to investigate fluctuations, and since the variables by and large co-oscillate, only price will be used as observation variable in the subsequent sensitivity runs.

For sensitivity to numerical parameters, the parameters are in general varied within a range of plus/minus 50 per cent of the initial value. Exceptions are notified. The key variable used in the sensitivity tests is the price, and the test input is a 10 per cent increase in *desired housing*. Sensitivity to table function assumptions is tested by changing the curve shapes of the table functions within reasonable values. All sensitivity tests from section 8.9.1 up to and including 8.9.13 in this chapter are made in base run mode, i.e., with fixed costs and no supply chain management in effect. Sensitivity to assumptions on variable costs is presented in section 8.9.13. Adding supply line management structure to the base model is tested in section 8.9.14.

8.9.1 PLANNING TIME AND CONSTRUCTION TIME

Figure 42 shows the sensitivity of price to various assumptions for time to plan. Normal time to plan is set to 1.5 years, and the sensitivity runs include 50 per cent off and 50 per cent above the normal time. Results indicate that the longer the planning time, the greater the wavelengths. There is also a larger amplitude for the longer planning time compared to the shorter. Wavelengths are approx. 14 years for the shortest planning time. For the longest planning time, the wavelength is approx. 17 years when oscillations stabilise, and about 16 years for the initial value of 1.5 years; the base run value.

Figure 42: Sensitivity of price to normal time to plan, 0.75, 1.5 and 2.25 years (graph 1, 2 and 3 respectively),



Sensitivity runs for the next key variable, labour, is presented in Figure 43 for the same range of values for planning time as in Figure 42. The characteristics for the graphs for the fluctuations in labour are that values change more sharply around the maximum curve points compared to the runs for price. Furthermore, the fluctuations are much more substantial for the labour and the jobless compared to price fluctuations. The reason for this is that labour and jobless are linked to construction, which is volatile compared to the entire stock of housing.

Figure 43: Sensitivity of employment to normal time to plan, 0.75, 1.5 and 2.25 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing

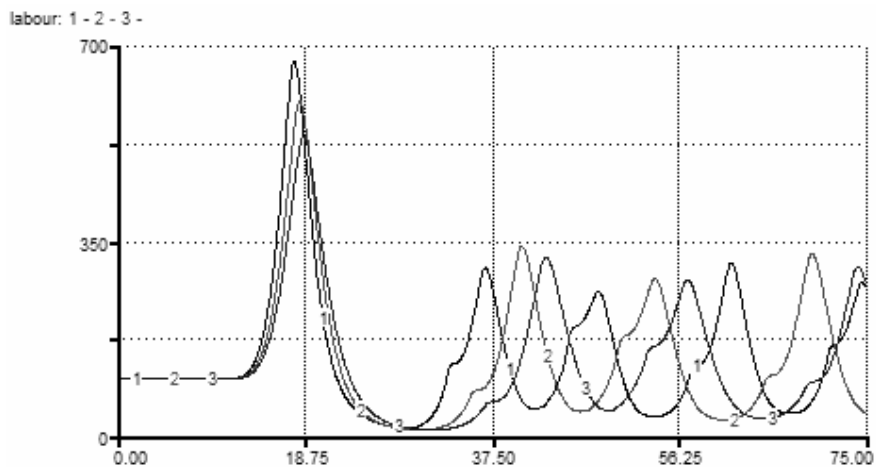


Figure 44: Sensitivity of jobless to normal time to plan, 0.75, 1.5 and 2.25 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing

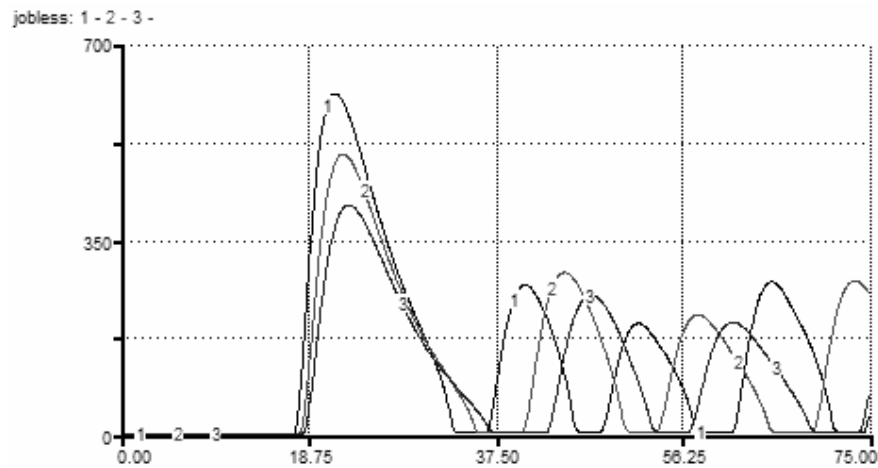
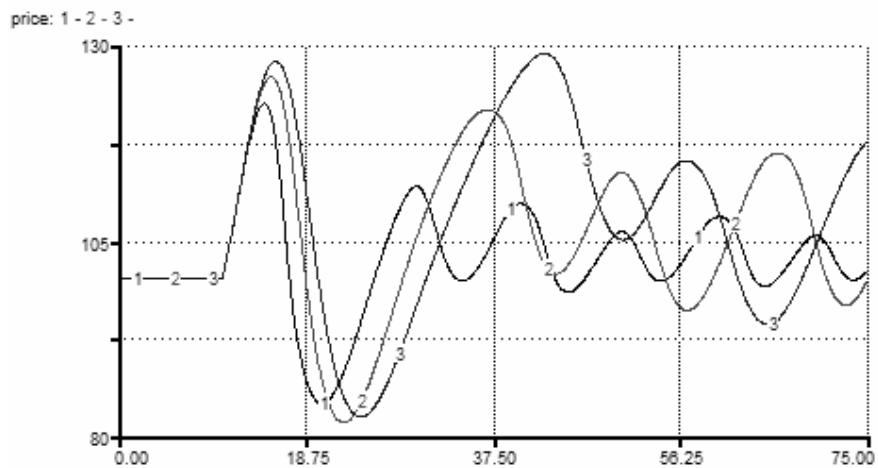


Figure 43 indicates that shorter planning time gives shorter wavelengths, of course similar to the price cycles. Running over a much longer time than 75 years, the length of the waves for price and labour converge to the same level (limit cycles) in this model for the base runs.

Construction times have a similar effect on price sensitivity runs as planning times to wavelengths and amplitude.

Figure 45: Sensitivity of price to normal time to construct, 0.75, 1.5 and 2.25 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



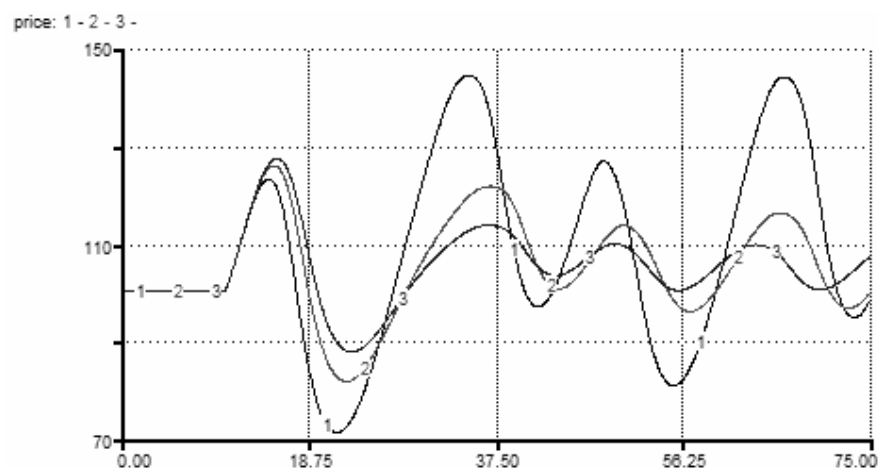
As for planning time, the effect of variations in construction time, 1.5 years normal time, plus/minus 50 per cent, indicate 10 years wavelength for the shortest construction time and approx. 20 years for a 2.25 years' length of construction time.

8.9.2 AVERAGE HOUSING LIFETIME

The differences to variations in housing average lifetime are considerable when lifetime is set to 50 years compared to 100 and 150 years. Therefore it is important to pay attention to this parameter. The question is quite critical, because “lifetime” is an unclear term.

Even when housing is “taken out of service” (see ¹¹ above), in order to be refurbished, or when smaller units are combined to larger, alternatively broken up to smaller, the *buildings* themselves are still in place. Buildings' average lifetime may possibly be hundreds of years (however, new “lean” construction methods probably reduce buildings' lifetime. Maintenance, refurbishing and restructuring change utility and value, requires resources, and play roles in housing supply and demand dynamics. On the other hand, demolishing buildings for replacing them with a completely new has the same function as refurbishing and restructuring, namely to provide up to date housing. For these reasons, the average housing lifetime is a very intricate parameter if the model shall be kept simple. As demonstrated in Figure 46, the sensitivity to average lifetime is considerable.

Figure 46: Sensitivity of price to housing average lifetime, 50, 100 and 150 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



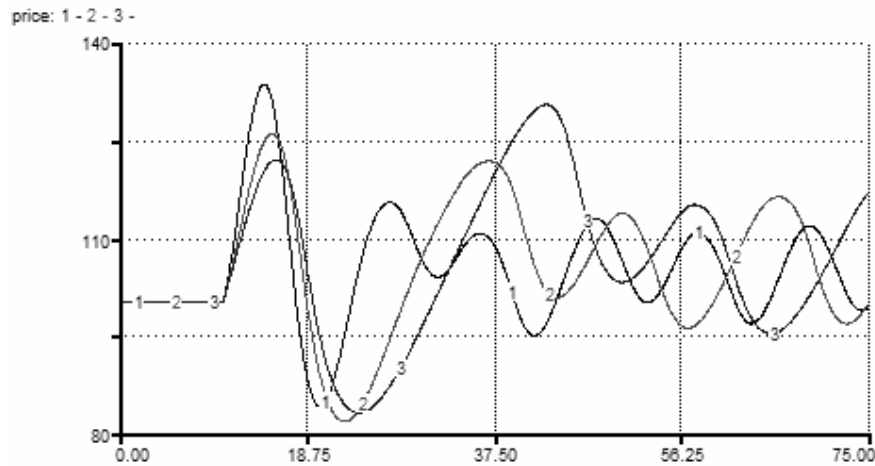
The various values of lifetimes, 50, 100 or 150 years, will have different implications for the average size of the labour stock. Wavelengths for price with respect to the different assumptions regarding housing lifetime vary from 18 years for a 50 years average lifetime and 14 years for an average lifetime of 150 years. For the base run assumption of 100 years the wavelength is 16 years. The shorter the lifetime, the more vigorous the cycles.

8.9.3 EXPECTED PRICE ADJUSTMENT TIME

DiPasquale and Wheaton (1996) found that fluctuations in the housing market arise with the assumption that people have “myopic backward-looking (or adaptive) expectations”. The literature review indicates that adaptive expectations are in effect. The sensitivity run for expected price adjustment time is based on a “normal” one year, plus/minus 50 per cent. As can be observed from Figure 47, the oscillations increase in amplitude for increasing adjustment times, and wavelengths become longer.

At values somewhat less than four months, the oscillations fade out with the base model’s parameter set. For longer adjustment times there are sustained oscillations, increasingly greater in amplitude and wavelengths. Wavelengths vary from 11 to 19 years for the runs in Figure 47, and with about 16 years for the base run value. Adjustment times exceeding 9 years give increasing oscillations.

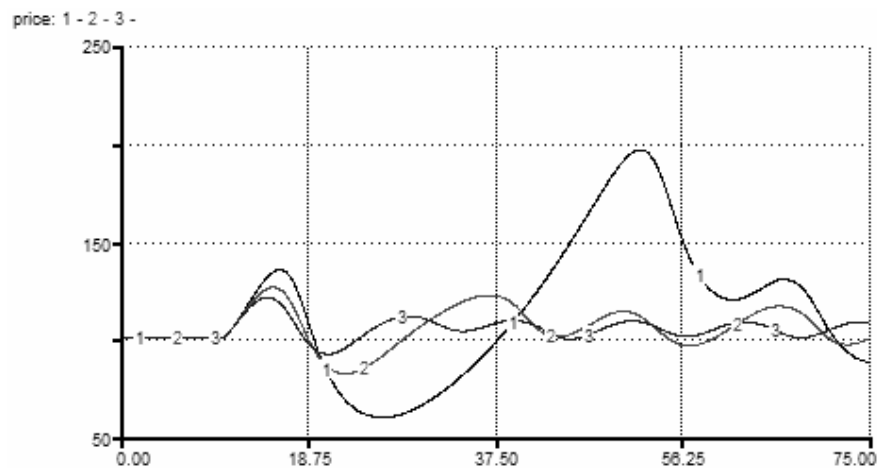
Figure 47: Sensitivity of price to expected price adjustment time, 0.5, 1 and 1.5 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



8.9.4 PRICE ELASTICITY

Figure 48 indicates the sensitivity to assumptions of price elasticity values. For the lowest value the variations both for wavelength and amplitude is significantly larger than for the “normal” elasticity and 50 per cent lower than the “normal” elasticity. For values moving towards -1, the oscillations are dampened.

Figure 48: Sensitivity of price to price elasticity, -0.2, -0.4 and -0.6 (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



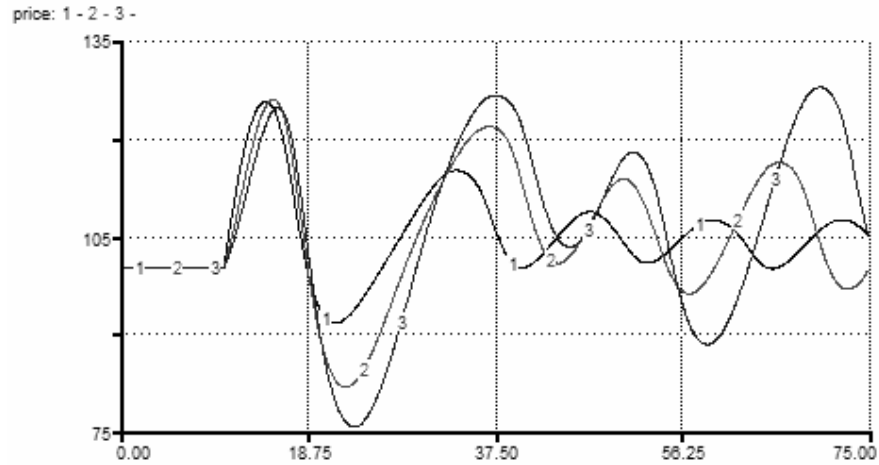
The wavelength for the elasticity with the highest absolute value is approx. 11 years, and when it stabilises beyond 75 years, the wavelength is 24 years for the lowest absolute value of the elasticity. The model is therefore sensitive to values of price elasticity, and this also raises the question of converting to variable price elasticity. From economic theory we know that the price elasticity moves towards zero when prices move towards zero.

8.9.5 HOUSING DEMAND

The *housing_demand* is a smooth function of *desired_housing*. The time to respond to *desired_housing* is initially set to 2 years, and the order to one. Figure 49 indicates the sensitivity for this parameter (*demand_delay_time*).

Different values of *demand_delay_time* indicate that longer delays increase cycles' amplitude and wavelengths. For short delays less than one, there are still oscillations. All results appear to be limit cycles, even when tested for much delayed demand response.

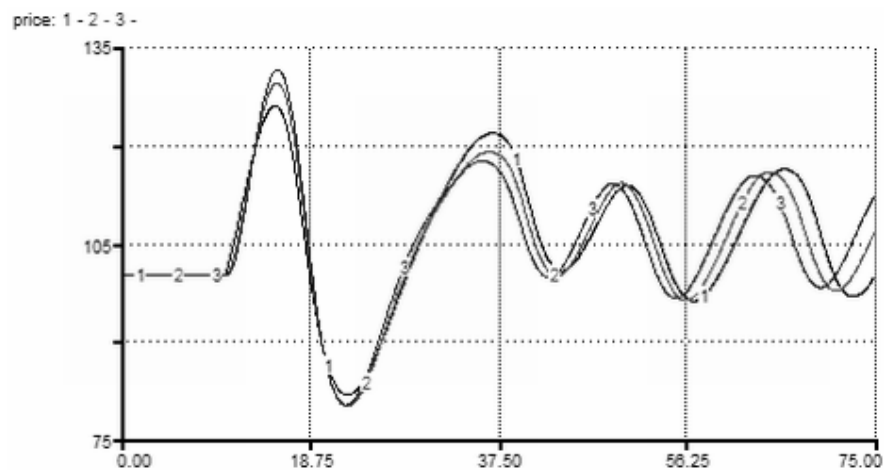
Figure 49: Sensitivity of price to demand_delay_time, 1, 2 and 3 years (graph 1, 2 and 3 respectively), smooth order 1



There are no known estimates for this delay time. It is probably “some years” and perhaps varying, depending on other conditions.

The order of the smooth function does not affect results much. The sensitivity to smooth order 1, 2 and 3 is indicated in Figure 50.

Figure 50: Sensitivity of price to smooth order values 1, 2 and 3 (graph 1, 2 and 3 respectively)

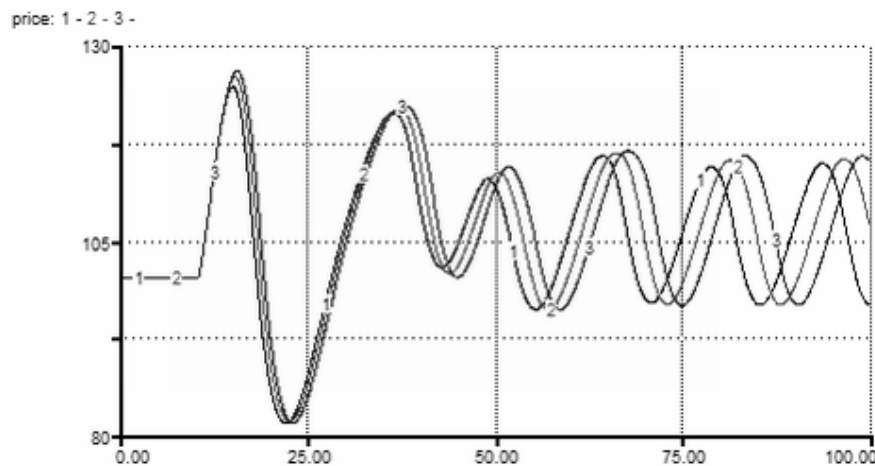


8.9.6 RECRUITS' TRAINING TIME, ATTRITION TIMES AND FIRING ADJUSTMENT TIME

Sensitivity runs for the various parameters in the capacity sector of the model; time to recruit, training time, labour and jobless attrition, and firing adjustment time show quite similar results regarding wavelengths. Sensitivity runs are illustrated in Figure 51 to 54. Simulation time has been set to a hundred years in order to display the “stabilised” range of the curves.

For the sensitivity to firing adjustment time, the amplitudes are decreasing for increasing values. The interpretation of this is when workers are kept in “the pool”; the construction company is able to react faster when demand increases after a downturn.

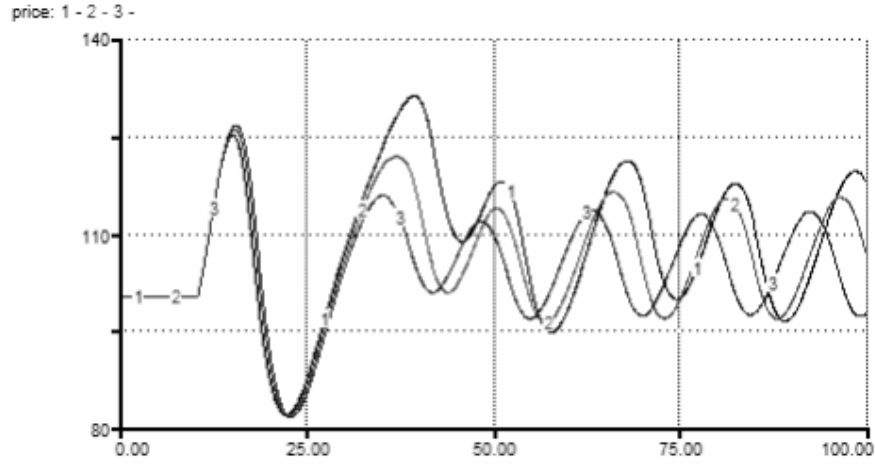
Figure 51: Sensitivity of price to time to recruit, 0.5, 1 and 1.5 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



The sensitivity of the key variable *price* to time to recruit is relatively insignificant - amplitudes are quite similar.

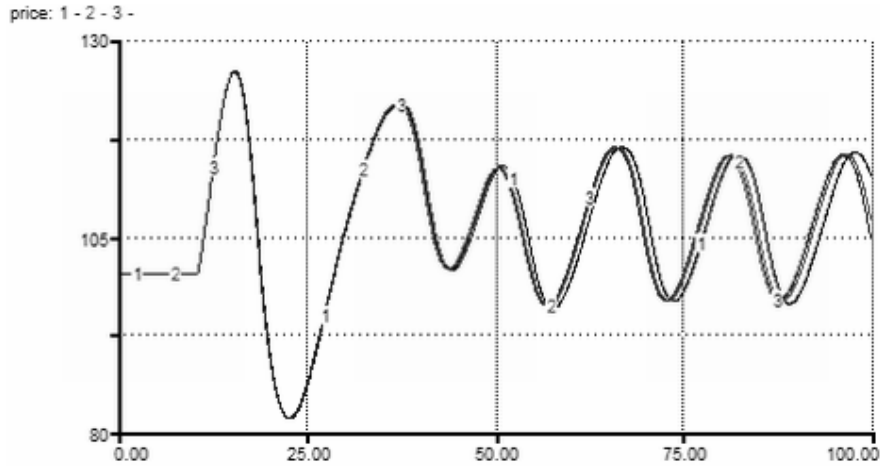
The sensitivity to training time is greater. Amplitudes decrease for increasing training time in the current range. For considerably higher values for training time the amplitude decreases and converges to limit cycles. The wavelengths become shorter the longer the training time. This is indicated in Figure 52.

Figure 52: Sensitivity of price to training time, 1.5, 3 and 4.5 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



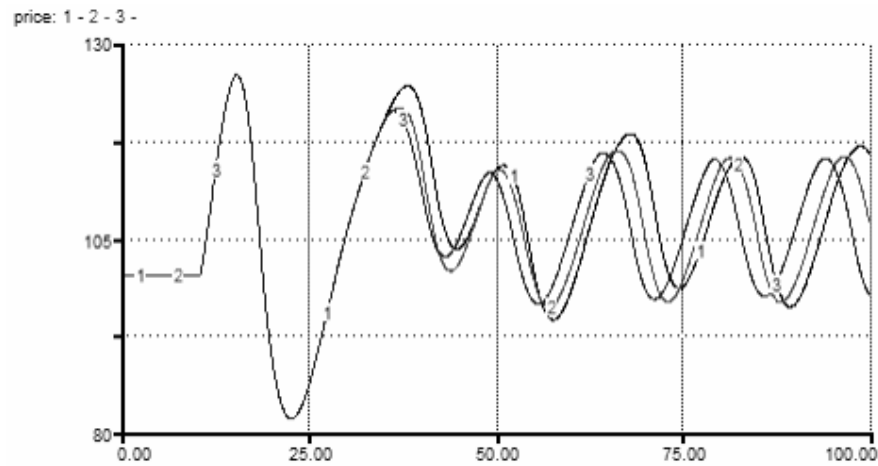
The sensitivity to labour attrition time as shown in Figure 53 is negligible both with respect to amplitude and wavelengths.

Figure 53: Sensitivity of price to labour attrition time, 5, 10 and 15 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



Much in line with the sensitivity to time to recruit, the sensitivity to jobless attrition time is moderate both in terms of wavelengths and amplitudes. This is shown in figure 52.

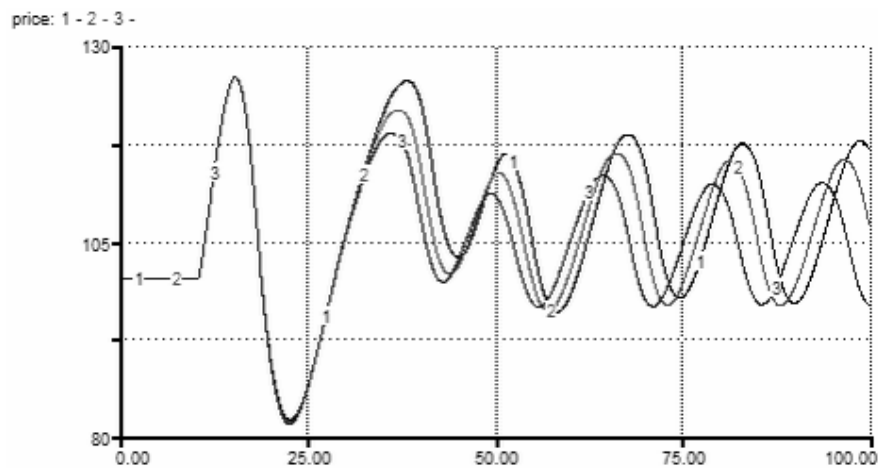
Figure 54: Sensitivity of price to jobless attrition time, 2.5, 5 and 7.5 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing



The sensitivity to variations in jobless attrition time is greater than for instance for variations in the labour attrition time for the chosen value sets.

For the sensitivity to firing adjustment time, the amplitudes are decreasing for increasing values. The interpretation of this is that when workers are kept in “the pool”, the construction industry is able to react faster when demand increases again after a downturn.

Figure 55: Sensitivity of price to firing adjustment time, 0.5, 1 and 1.5 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing

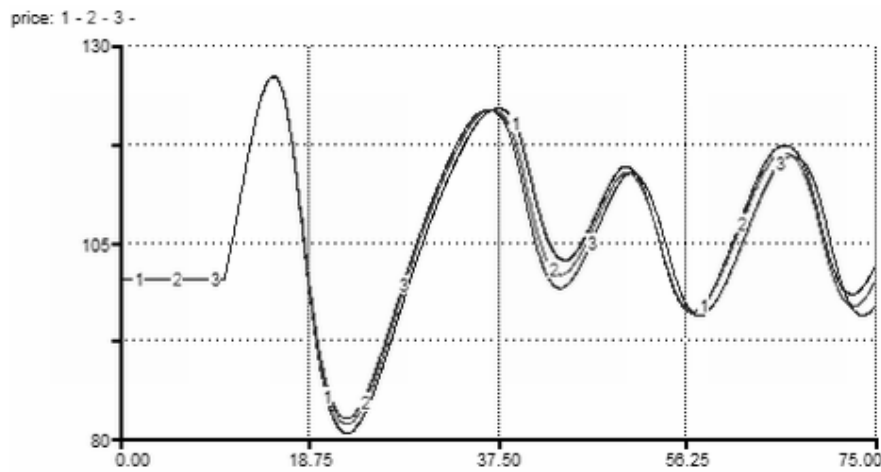


All parameters in the “capacity sector” of the model have quite moderate effects for the results in the “market sector” of the model. The range of wavelengths is approx. 14 to 16 years for the observed value – price.

8.9.7 HOUSING GAP ADJUSTMENT TIME

The difference between housing demand and the housing stock, i.e., supply of housing is represented by the housing gap, for which there is a housing gap adjustment time. Figure 56 illustrates the sensitivity to assumptions about the housing gap adjustment time. The figure indicates that the housing gap adjustment time, compared to other parameters, has a negligible effect.

Figure 56: Sensitivity of price to housing gap adjustment time, 0.5, 1 and 1.5 years (graph 1, 2 and 3 respectively), for a step increase of 10 per cent in desired housing

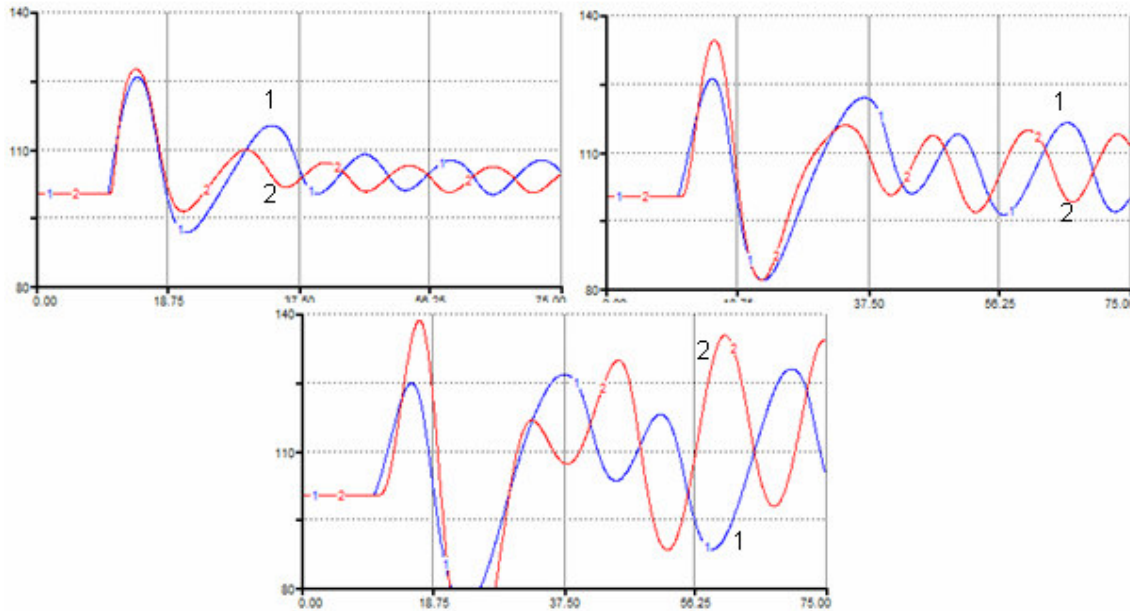


8.9.8 HOUSING DEMAND SMOOTHING FUNCTION

The housing demand in the model is a function of desired housing, i.e., desired housing at current expected price. Housing demand is a smoothed function of desired housing, reflecting an assumption that people do not react immediately to changes in expected price. An important question is how fast people react in terms of demand when expected prices change. A first order delay with a two years averaging time was employed in the base run. In the sensitivity runs illustrated in Figure 57, average delay time has been set to one, two and three years, and the smooth order has been set to 1 and 6.

The observed variable price fluctuates in all runs, however increasingly for increasing delay times and order – the model is relatively sensitive to various assumptions for the delay in response time from a desire to buy at current prices to actual demand.

Figure 57: Sensitivity of price to different smoothing and averaging times for a ten per cent step increase in desired housing. Upper left curves 1 year, upper right curves 2 years, lower curves 3 years. Order 1 and 6 (curves 1 and 2 on each graph respectively)

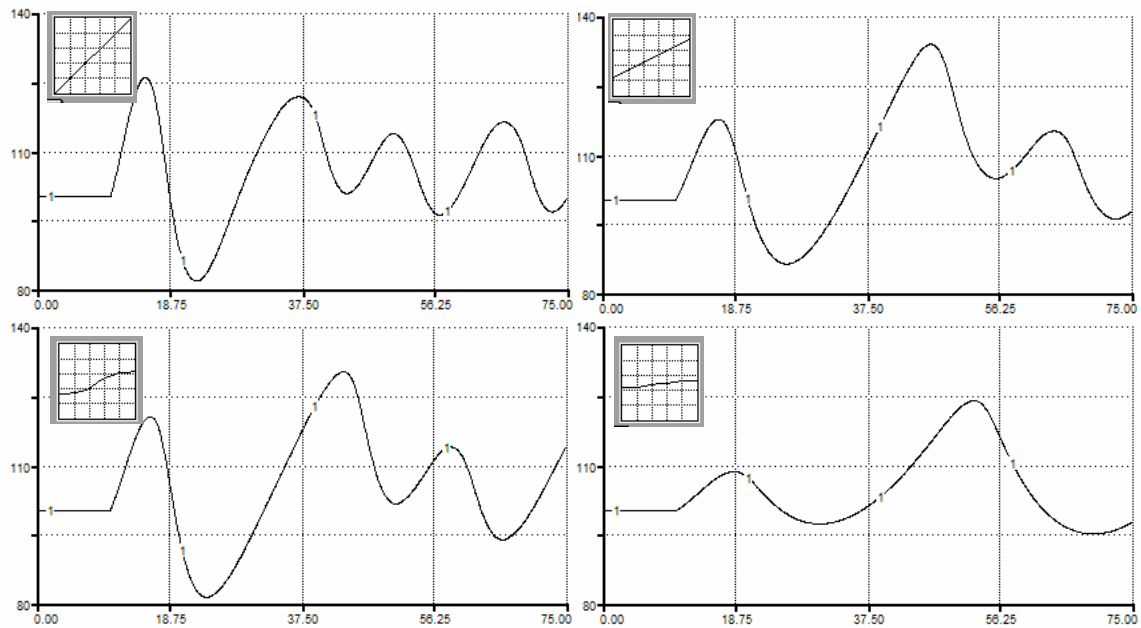


8.9.9 EFFECT OF DEMAND/SUPPLY RATIO ON PRICE

The model base runs under different assumptions for the table function “effect of demand supply ratio” are presented in Figure 58. The first (upper left) is based on direct input of the ratio ($\text{housing_demand}/\text{housing_stock}$), i.e., $\text{effect}=\text{ratio}$. In the following model sensitivity runs, upper right, the effect equals $(\text{ratio}/2 + 0.5)$, and, in the lower left and lower right S-shaped curves with values ranging from 0.7 to 1.3 and 0.9 to 1.1 respectively.

Shapes are critical, because the four runs under the various assumptions diverge from each other in different ways. Which one that is “correct” is difficult to decide upon, because statistics suitable for estimation have not been available.

Figure 58: Sensitivity of price to the “effect of demand supply ratio”, for a step increase of 10 per cent in desired housing

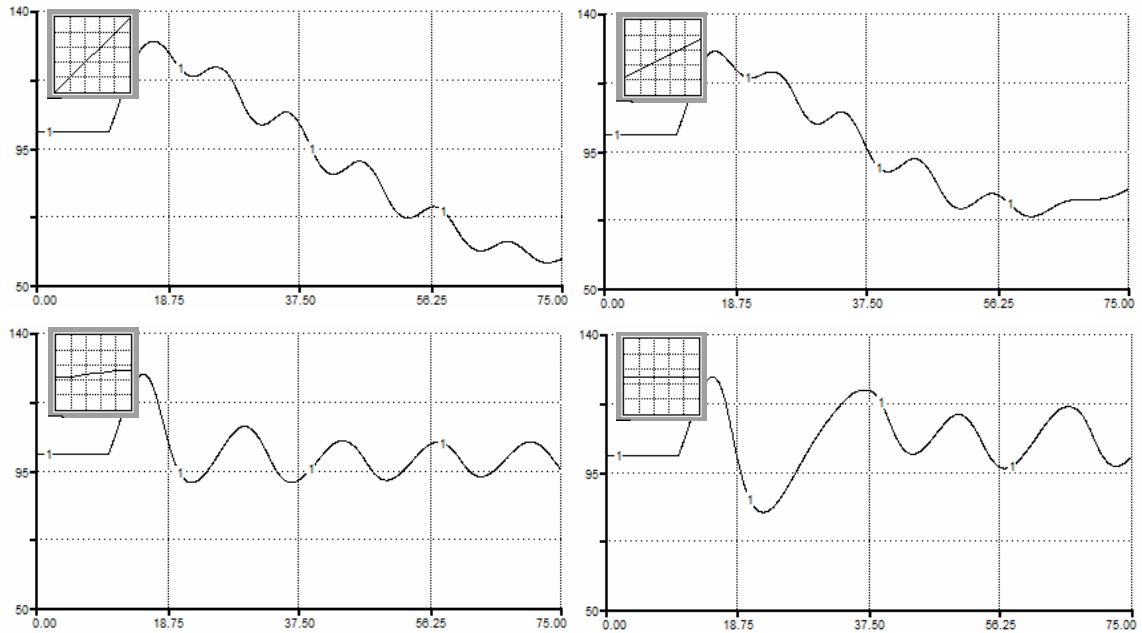


8.9.10 EFFECT OF DESIRED CAPACITY TO CONSTRUCTION CAPACITY RATIO ON COSTS

The sensitivity runs for testing shapes for the function “effects on cost” has been carried out for three alternatives in addition to constant cost used under the base run. This is illustrated in Figure 59. Similar to the testing of effects of demand supply ratio for the effect on price, the alternatives for cost include direct input of the ratio (desired_capacity)/(construction_capacity), i.e., effect=ratio in the upper left run. The upper right assumption for model sensitivity corresponds to an effect equal to $(\text{ratio}/2 + 0.5)$. In the lower left run, the effect is represented by an S-shaped curve with values ranging from 0.9 to 1.1, and the lower left curve is the base run alternative; constant costs.

The two upper runs are quite different from the next two in terms of curve shapes. The lower left curve has shorter wavelength and smaller amplitude compared to the lower left, which corresponds to the fixed cost alternative in the base run. Which one that is “correct” is difficult to decide upon, because statistics suitable for estimation are not available. The runs indicate that the model is relatively sensitive to the assumptions for effects on cost.

Figure 59: Sensitivity of price to the “effects on cost”, for a step increase of 10 per cent in desired housing

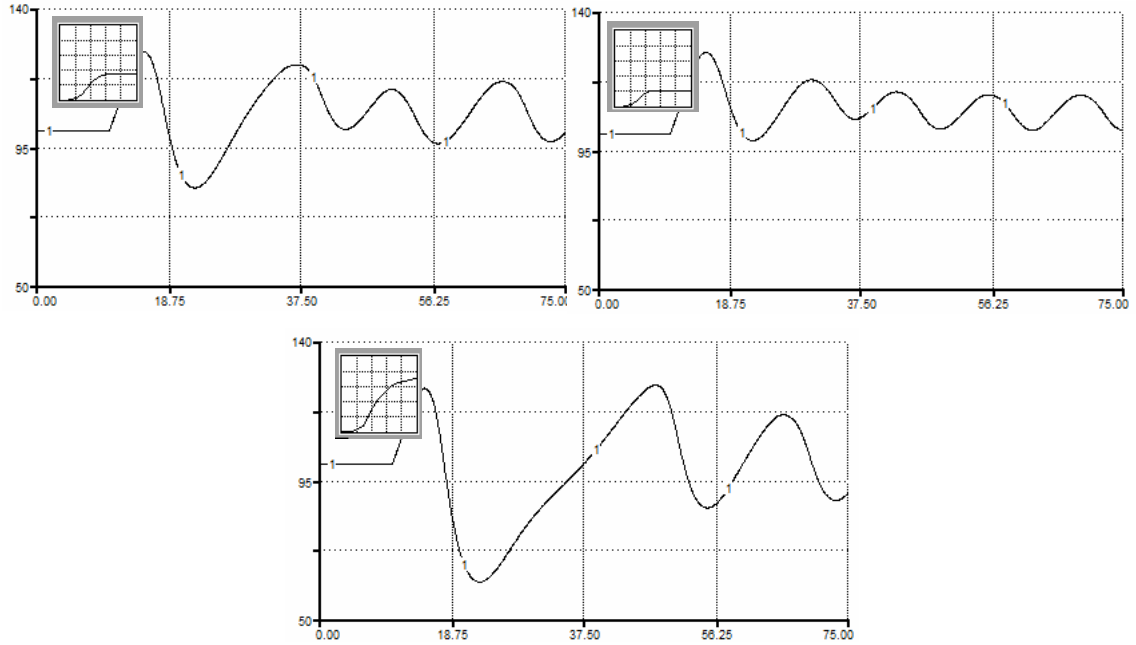


8.9.11 EFFECT OF THE PROFIT INITIATION FUNCTION

The profit initiation function takes value 1 when the profit rate ($(\text{expected_price} - \text{expected_cost}) / \text{expected_cost}$) equals zero. Still, for negative values of the profit rate it is assumed that planning initiation takes place, however less than for positive profit rates. In Figure 60 the upper left graph is based on the same table function values as in Appendix 2, with 3.7 as the highest value. In the upper right curve the shape has been changed to lower values for positive profit rates, with a maximum of two. The lower curve has a maximum value of 7.

Assumptions for the shape and maximum values for the profit rates give significant differences; the model is sensitive to the profit rate initiation function. There is no information available for an estimation of this relation.

Figure 60: Sensitivity of price to the “profit rate initiation function” for a step increase of 10 per cent in desired housing

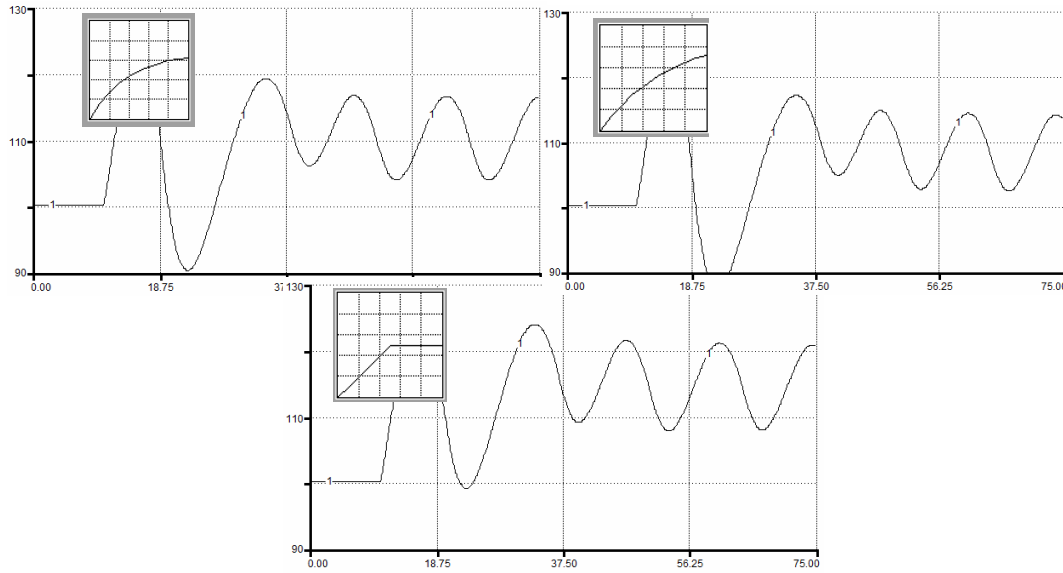


8.9.12 FUNCTION OF DESIRED ADDITIONS TO CONSTRUCTION CAPACITY RATIO

This function, with the cryptic name $f_{desadd_to_cc_ratio}$, is a function that substitutes a so-called MIN function – giving a “softer” and more realistic development than a MIN function for capacity utilisation. The alternative for the *planning_start_rate* had been to multiply the profit rate initiation function with $\text{MIN}(\text{desired_additions}, \text{construction_capacity})$. In Figure 61 that corresponds to the lower curve.

The table functions for the two upper curves have a somewhat different shapes, though values for all the three table functions starts in (0,0) and intersect (1,1). All resulting curves for price have almost the same shape, both for wavelengths as well as amplitude. The test indicates low sensitivity to various table curve shapes.

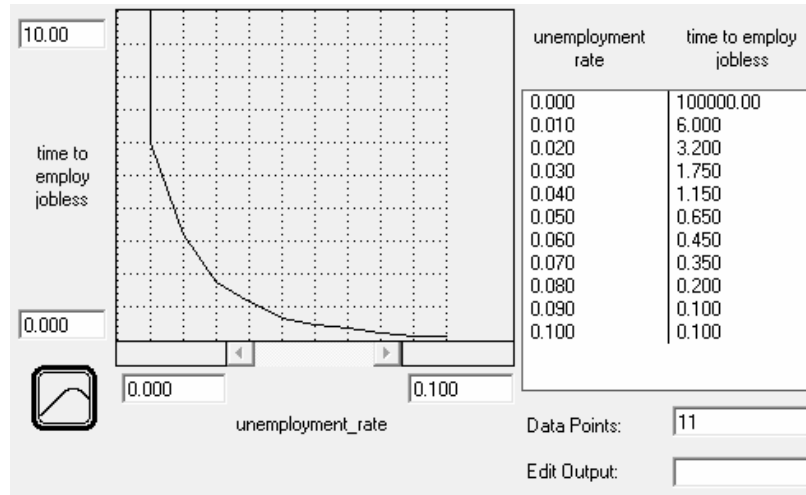
Figure 61: Sensitivity of price to the desired additions to construction capacity ratio for a step increase of 10 per cent in desired housing



8.9.13 CONSTRUCTION CAPACITY UTILISATION AND TIME TO EMPLOY JOBLESS

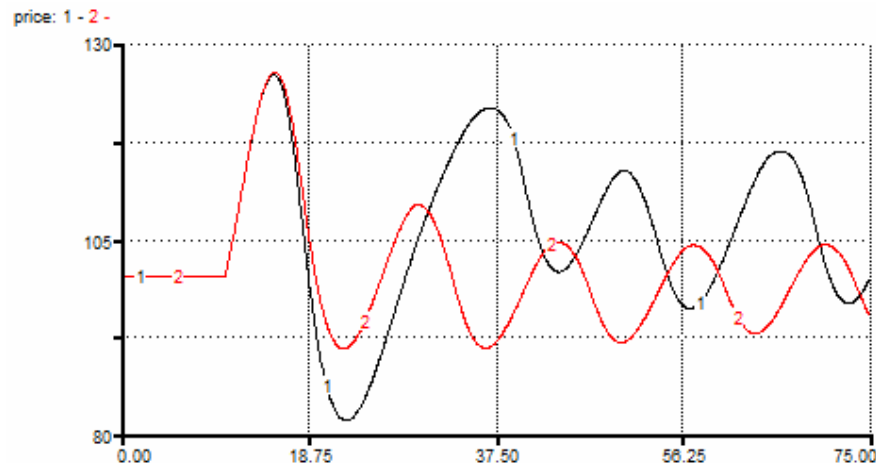
The table function *construction_capacity_utilisation* gives similar results as in Figure 61. For this reason, different shapes of this table function are not critical if they start in (0,0) and intersect (1,1).

The table function *time_to_employ_jobless* starts with an “infinity” value for unemployment rates close to zero. The interpretation of this is that time to recruit jobless takes much more time when unemployment is low, compared to situations when unemployment is high. For unemployment rates at about 10 per cent, the table function’s value for time to employ jobless is 0.1 year, which may be realistic. The sensitivity of the chosen indicator variable, price, to different curves of the same shape for the table function, but quite different levels, is very low. For instance, multiplying all table points with 10, i.e., that it will take at least one year to employ jobless, does not affect the observed indicator’s development over time substantially.

Figure 62: Table function for time to employ jobless from the base run

8.9.14 THE EFFECT OF VARIABLE COSTS

In the base run costs were assumed fixed. The introduction of variable costs, using the pressure in the construction activity as input, changes the model behaviour. This also has possible policy implications that shall be discussed in section 9.2. Figure 63 illustrates the effect of variable costs compared to fixed costs. As the illustration in Figure 63 shows, the implications of introducing variable costs give dampened oscillations compared to the fixed cost assumption, and also more frequent oscillations.

Figure 63: Sensitivity of price to fixed cost (curve 1) compared to variable cost (curve 2) for a ten per cent step increase in demand

Running the model for more than 75 years indicates that the oscillations persist, however, they are still less severe than for the fixed cost alternative. The wavelengths when the oscillations stabilise are reduced from approx. 15 to 12 years for variable cost compared to the fixed cost assumption.

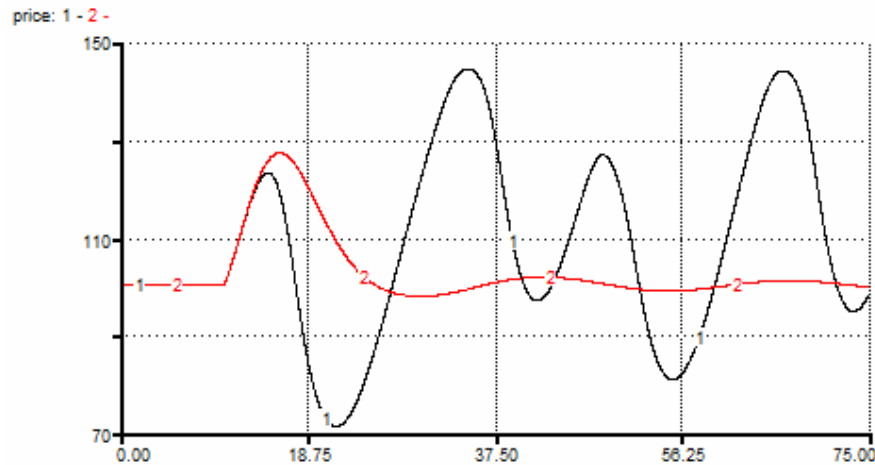
8.9.15 ADDING MANAGEMENT TO THE SUPPLY CHAIN

The aggregate housing supply chain consists of many competing actors. The chain is unmanaged in the sense that actors may not consider how much there is in the total chain, and the consequences for how completions builds up the housing stock that consequently result oversupply.

In a single company that shall cope with incoming orders and keep an inventory sufficiently ample to meet expected orders, the chain can be managed. The company is capable of registering what is in the chain, and to correct production accordingly (Sterman (2000) states, however, that chain management in practice often not is in place). If the total housing supply hypothetically were administered by one single body, chain management could have been implemented. Alternatively, regulations could be put in place.

Figure 64 indicates, hypothetically, how supply chain management will work compared to the base run. While the base run results in sustained oscillations, the results for the managed chain are relatively much more dampened oscillations, though adjustments still takes a long time.

Figure 64: Sensitivity of price to unmanaged supply chain (curve 1) compared to a managed chain (curve 2) for a ten per cent step increase in demand



In the chapter on policy considerations, further discussions on chain management will be presented.

9 POLICY CONSIDERATIONS

The sensitivity tests indicated that changing values for some of the constants and table functions in the model have considerable effects on model simulation results. Some of the parameters and functions may be changed or controlled by decision makers in the real world. Therefore, to the extent that the model reflects realities, these parameters are in fact policy parameters. Changes in the model structure are also policy options.

The model testing indicated that supply chain management (see Figure 64) incomparably had significant effects for dampening cycles (as also *normal_time_to_plan* and *normal_time_to_construct*, however, these had to be set to unrealistically low levels). Instead, efforts towards introducing a system that may be used in a market with many competing real estate developers should be the preferred means for the purpose, if feasible. Two strategies are obvious, an information strategy, and/or direct regulations, for instance through the number of permits given. These two options will be discussed first. The next observation giving considerable effect on cycles was the introduction of variable costs instead of fixed costs – this is the next topic to be discussed. In the following sections, possible policy parameters including table functions will be focused, and then different policies for demand stimulation.

9.1 MANAGING THE SUPPLY CHAIN

9.1.1 INFORMATION STRATEGY

So-called indicative planning (Johansen (1978)) in market economies is the term for a principle, by which the central authorities' make efforts to overcome market failures caused by imperfect information. Imperative planning is the opposite principle – a principle best known from centralised economies.

Statistical figures of housing units and floor area for General permits, construction work started and completed are necessary components in an information strategy. Such statistics should not only be presented nationally, but also regionally. In recent years the tendency has been to present fragmented statistics nationally, and only for relatively short periods. One of the reasons for this may come from changes in definitions and consequently broken time series. Long time series of statistical information are needed for analysing long term trends or movements, such as cycles. Giving significance to indicative planning also means that the statistics not should be available from different bodies and in other ways fragmented, but presented from an information pool in order to easily provide real estate developers and sales organisations with appropriate statistics in due time. Construction starts are published by Statistics Norway, however aggregate and usually just for shorter recent periods. The number of permits given is not easily available.

Another aspect with an information strategy is to “teach” actors how the market functions. The fluctuations' wavelengths are apparently so long that “newcomers” among analysts and planners in the industry hardly are aware of this phenomenon. The main focus among actors in the industry has recently, in the boom, been on *increasing* costs and prices. The responsible Ministry in Norway has established a programme for stabilising the costs; however, increasing costs may very well be caused by the boom. An increased focus on cycles is probably relevant to announce to the players in the industry.

9.1.2 DIRECT INTERVENTION

Another strategy is more of the “imperative planning” principle; “you shall...” or “you shall not...”, for instance to dampen down or boost planning and construction starts according to forecasts and how much there is in the supply line. Restricting or controlling the number of permits could be part of such a strategy. However, this will also depend on data similar to what an information strategy will require, hardly available today and perhaps not in line with what market oriented politicians will accept. Direct intervention will also require the establishment of a body able to make proper analyses.

Johansen (1977) points out that decisions made by the central authorities might have severe consequences if the central authorities’ judgements are faulty. Decisions made by many de-central decision makers on the other hand, may be more or less “correct”, however the results of these decisions will outweigh each other, giving a result that is “averaged”; not necessarily optimal, but perhaps better than incorrect central decisions²⁵. The probability that all decentralised decision makers have the same judgement is probably negligible, but decisions may be based on “herd instincts” and biased information, spurred by spokesmen for the industry, may cause results far from optimal.

9.2 TAXES AND SUBSIDIES

9.2.1 CONSTRUCTION COST MODIFICATIONS

As indicated in the comparison between the base run with fixed costs and the refined model with variable costs, the variable cost model run performed better regarding the amplitude of the oscillations (Figure 63). A proper question is whether taxes and/or subsidies as policy instruments could have a dampening effect. There have been various subsidies and taxes both on housing production as well as housing consumption. These taxes and subsidies

²⁵ Johansen (1977) cites Tinbergen: “Central decisions may imply bigger mistakes than decentralized decisions, since the latter are taken by a larger number of individuals whose decisions, when wrong, may partly neutralize each other.” This is based on a consideration that decentral decision makers have different sources of information and different judgements. Today the press quotes a few proponents that often, but not always, have parallel ideas – this may be a centralisation of the basis for decisions, even if the structure formally is decentralised.

have been part of housing and fiscal policies, however, never for regulating *cycles* in the housing market. During the 1990-ies the pressure in the construction increased steadily, and for this reason the Norwegian Parliament proposed a cycle tax for the construction of office and industrial buildings in 2001 (Stortinget (2001)) in order to reduce the pressure in the construction industry. The industry's spokesmen protested against the tax, and the proposal was not implemented.

A subsidy, or removal of an existing tax totally or partially, could be appropriate when the activity in the housing construction industry is considered too low. When the pressure is considered too high, removal of subsidies or tax increase could be implemented. The problem is possibly the timing of this policy and how it will work. For taxes and subsidies compensating the suppliers', the profitability will change. The tests of assumptions for the *effects_on_cost* graphs in Figure 59 may be seen as various compensations by means of taxes/subsidies for variations in the pressure in the housing construction industry. Using the results from the testing of sensitivity to various assumptions about costs indicate that using taxes and/or subsidies can be very difficult. The curves for the observed price variable demonstrate quite different patterns, though, all are oscillating. Sterman (2000) refers to the economists Friedman and Phillips, maintaining that "...stabilisation of the business cycle through government monetary and fiscal policy is difficult. Policy levers such as tax and interest rates do not alter the underlying feedbacks or parameters of the inventory-workforce structure and thus are unlikely to inherent oscillatory behaviour".

Provided that the model reflects the real world sufficiently well, the sensitivity runs for various shapes of the function *effects_on_cost* demonstrates Sterman's arguments. Consequently, cycle taxes and/or subsidies for compensating effects of cost cycles are probably not feasible policies.

9.3.2 ADJUSTING DEMAND

A question is whether the conclusion for cycle-compensating taxes or subsidies on the demand side is valid also for the demand side. For instance, trying to dampen the demand by some means when prices are high related to "normal" price or to expand demand when prices are low.

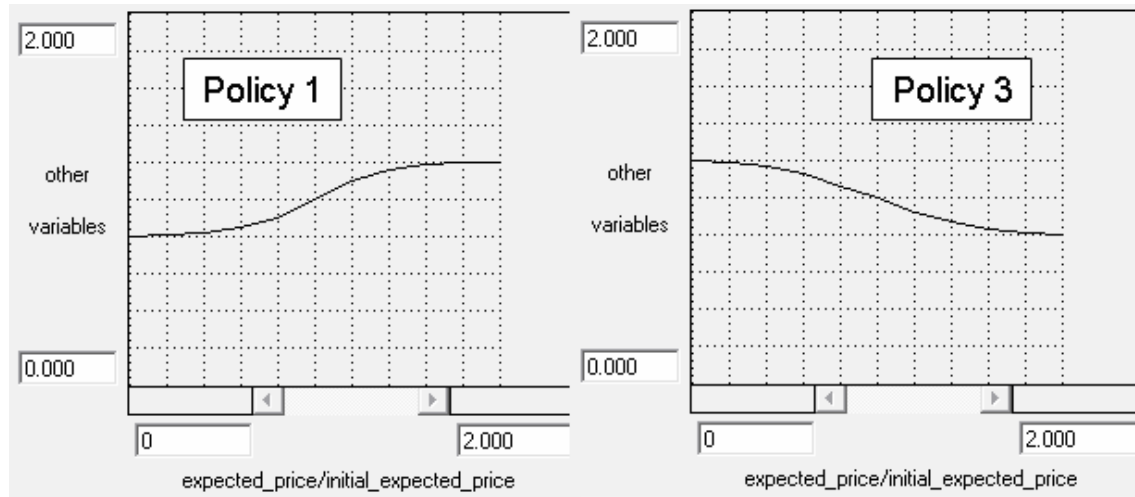
Housing has been subsidised heavily in post-war Norway, among other things through the system of tax compensation for interest expenditures up to the 1980-ies. The Norwegian State Housing Bank (NSHB) financed much of new housing with favourable terms and low interest rates. Since then these subsidies have been reduced gradually. The NSHB now plays a role most for supplying economically less advantaged groups and young people who establish themselves with housing. Furthermore, there are still arrangements with housing allowances for the disadvantaged groups. However, these subsidies and allowances have not been used for compensation for *cycles* in housing prices. Such instruments are introduced when the problem is recognised, and they will probably be withdrawn when the problem is solved permanently for other reasons. Though, efforts to strengthening such arrangements during the recent long term price increases have been made by the authorities by means of the Housing Bank. If the price increases are consequences of a boom in the housing market, such efforts can be considered as compensation for cycles. However, cycles are hardly mentioned. Price and cost *increases* have been considered as a continuing process, and some people have to be compensated. There are no automatic plans to withdraw such compensation arrangements. This will imply more allowances when housing prices are high compared to when prices are low. Presumably, the effect of strengthening the housing demand from disadvantaged groups when prices are booming will have a reinforcing effect (in line with a new phenomenon; young people supported by parents when they are establishing in the housing market).

For those already established in user-owned dwellings, their homes are part of their assets. When prices decrease, the value of the housing stock also decreases. The timing of selling and purchasing housing for home-owners is therefore critical, for instance when selling after a purchase of a new home that is an unfavourable outcome when prices are decreasing. Prices may decline more rapidly than they increase. After the deregulation of the financial markets and the housing market, private financial institutions have increasingly financed purchases of housing. Private financial institutions tend to be more restrictive to give loans during recessions than during expansions in the economy. The terms for loans also tend to vary when assets change value. During the current boom that started 1992-93, banks have been willing to grant loans to more than 100 per cent of the value of housing object, expecting that the value of housing assets are going to increase also in the long run. When housing values decline, financial institutions reduce their approvals according to the value of

the existing housing stock, using 80 per cent financing or less for a declining asset value. Additional efforts may also be taken for implementing a more careful policy. This is a policy that may be rational for the individual financial institution, however, not necessarily in terms of what is beneficial for the whole community.

The financial institutions' policy of reducing the propensity to granting loans at favourable terms in recessions, and expansion in growth periods is presumable a cycle-expanding mechanism. Modelling financial institutions and the authorities' behaviour in this respect in the current model could be to use a table function directly on *housing_demand* or *desired_housing*. Input to the table function may for instance be the ratio between *expected_price* and *initial_expected_price*, or in the real world based on a housing price index relative to the consumer price index, however, surely difficult to practice.

Figure 65: Table function effect on desired housing for financial institutions' and/or authorities' policy



The effect of other_variables to desired housing is one for no effect, and the two alternatives “policy 1” and “policy 3” indicated in Figure 65.

The results of the simulation are presented in Figure 66, and the base run and the curves in Figure 65 represent three alternatives, i.e., policy options;

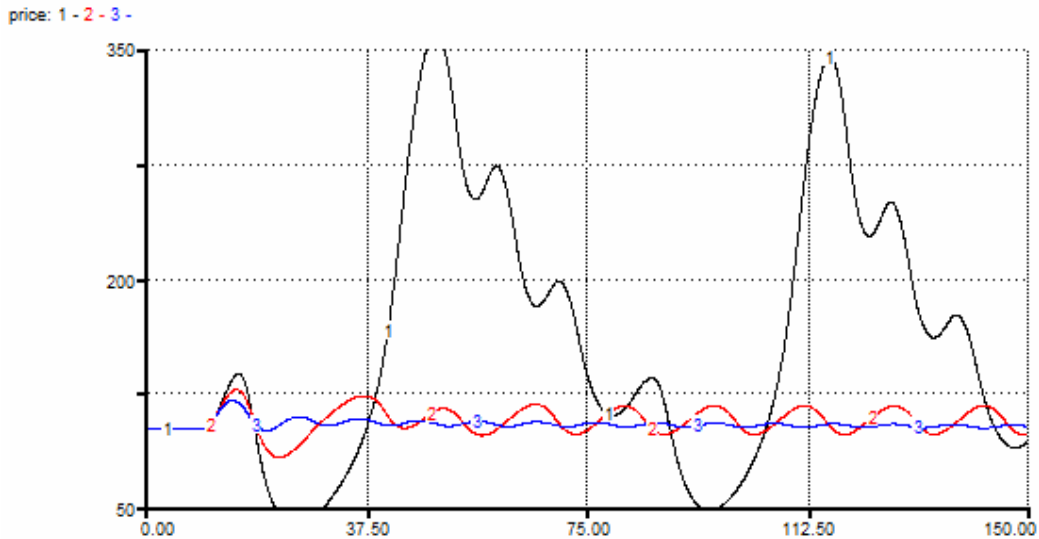
Policy 1: Private financial institutions' behaviour and current public policy²⁶ is in effect, i.e., demand contracting effect when housing prices are low related to "equilibrium price", and demand expanding effect when prices are high related to the "equilibrium price" (i.e., *initial_expected_price* in the base runs)

Policy 2: Results from the base run. This may be interpreted as a neutralising effect, i.e., if the authorities counterbalance the retraction or expansion effect by private financial institutions.

Policy 3: A public authorities' cycle counteracting policy that more than outweigh private financial institutions' policy is in effect, i.e., demand stimulation when prices are low and demand suppression when prices are high.

The runs in Figure 66 are base runs, only modified by the assumptions with respect to *other_variables* for policy 1 and 3. (The base run implies fixed costs and no supply line management). In Figure 66, the curve 2 represents the base run result, however, in terms of policy with the interpretation given in point 2) above. As can be observed from the figure, the "policy" 1 expands cycles in key variable price very much compared to the other two. Policy 3 has a considerably dampening effect on cycles, while "policy" 2, the base run, gives results in between 1 and 3, however, with significantly smaller amplitude compared to alternative 1 with the current model. Policy 3 implies converging cycles. The policy 1 gives "irregular" cycles, perhaps in line with conclusions for a similar policy in the simulations performed in Borgersen, Sommervoll and Wennemo (2006), referred in the literature review: "Periods of mild oscillations are mixed with violent collapses in an unpredictable manner". Policy 1 and two have both sustained cycles, while the cycles of policy 3 converges.

²⁶ The effect of the public policy of supporting disadvantaged groups may probably reinforce the total demand when price is greater than the "equilibrium price", not necessarily when price or expected price is less than equilibrium price, because withdrawal of support is likely to occur when prices are low.

Figure 66: Sensitivity of various policies to price for a ten per cent step increase in demand

The conclusions are different for instruments used on demand compared to the supply side. An explanation to this is that the instruments are not “symmetrically” equal. For the supply side the pressure indicator desired to actual construction capacity ratio was employed. For the demand tax/subsidy policy the price related to “normal” price is used.

9.4 PLANNING AND CONSTRUCTION TIME

The parameter *normal_time_to_plan* and *normal_time_to_construct* are model constants. However, decision makers may change these values. Therefore these parameters are policy parameters. Oscillations appear, according to Sterman (2000), from systems with balancing loops with significant time delays. Such delays cause the self-correcting loops to overshoot and undershoot because the loops’ correcting actions are coming into effect “too late”. Reduction of time delays is a means of dampening oscillations. Actually, efforts are made to reduce the time for the planning authorities to reduce planning time. Public planning time is expected to be reduced for instance by means of information technology. The construction industry itself is also striving for reducing construction time, among other things by using prefabrication, for instance by factory based module construction. Prefabrication will also have implications for the cost of production.

Figure 44 and Figure 45 show the effect of various delay times for planning and construction respectively. Reduction of these delays from “normal” to the half has significant

effects. The question is whether it is practically possible to reduce that much. The combined effect of cutting both delays increasingly reduces oscillations' amplitude. On the other hand the frequency increases. Changing both time to plan and construct to around 0.3 years or less causes a convergent result for the key variable - price. This is of course out of range for what is feasible. The model simulations indicate that efforts to reduce, or not to increase, will be favourable in terms of reducing cycles.

One of the interviewees (Appendix 3) maintained that the public planning office responded with longer planning time when the construction industry was busy compared to "normal" periods. The effect of a queue will increase both oscillation amplitude as well as wavelength. This could be modelled in a similar way as for construction labour. The conclusion here is based on a model run with an "effect on planning time" with desired and actual *planning* capacity as input by means of a table function to the flow *construction_start_rate*, similar to the structure behind the *completion_rate*.

9.5 PRICE AND COST EXPECTATION ADJUSTMENT TIMES

The sensitivity test indicated that various assumptions for price and cost expectation adjustment times affect model run results considerably. For this reason, this may also be considered interesting for policies. Well-timed information may contribute to reduce cycle amplitudes and wavelengths; however, as shown in Figure 47 the results are ambiguous within particular ranges. Running a similar test for the *expected_cost_adjustment_time* (this is not shown above) creates the same patterns as we can observe in Figure 47. On the other hand, beyond that range, increasing values for, the expected price and cost adjustment times, the cycles become increasingly stronger as delay times increases.

10 SUMMARY AND CONCLUSIONS

The hypothesis that the housing market system itself produces cycles disturbed by occasional external events is supported by the model tests. Econometricians have focused on the effect of interest rates, employment etc.; however, the current model runs indicates that for instance interest rates not are fundamental (employment has not been considered). On the

other hand, variations in interest rates as well as employment, growth in the population and consumption, or GDP, may *perturb* the system, causing cycles created by the delays in the system. The market breakdown from 1987/88 is probably most of all caused by the cyclical nature of the system, while the variations in other factors have strengthening or dampening effects. The breakdown in 1987/88 coincided with high interest rates, unemployment and a decrease in consumption per capita. Furthermore the deregulation of the financial institutions may have had effects. Kiøsterud (2005) refers to Mr. Skånland, formerly the director of the Central Bank, who commented on the crisis within the banking, property and housing sector as “bad banking, bad policy and bad luck”.

The lack of proper time series for various indicators is not necessarily a problem for testing the dynamic hypothesis. However, in order to calibrate the model for testing model behaviour compared to historical data and for forecasting, this is obviously an obstacle. Therefore, some of the actors in the industry are also proponents for better and more accurate statistics for the construction industry. The analyses based on the housing model indicate that information for monitoring the supply chain at least make decision makers *able* to react accordingly. As indicated, direct intervention, for instance by means of regulating the number of construction permits, may have dampening effects to cycles. However, one may question whether this is practicable or not.

Cycle taxes are actually proposed in order to regulate the construction of office building on the supply side. Model results indicate that this policy is not feasible. On the other hand, properly designed cycle taxes/subsidies implemented on the demand side seems to have a counter-cyclical effect. Timing is of course critical. It is a question whether politicians will take the risk to propose such a policy. The sensitivity analyses indicate some other instruments for dampening cycles, however not as significant as those referred in this summary.

The ongoing debate regarding housing prices and costs has mainly focused on the *increases* over the last 15-16 years. Cycles are hardly ever discussed. Much attention has been paid to the increasing costs of construction, however, these increases may very well be caused by which phase of the cycle we are in, not that costs are a problem in the long run (however, prices for construction ground is increasing because of increased density of buildings in pressure areas).

11 PROPOSALS FOR MODEL ENHANCEMENTS

11.1 VACANCIES

Maisel (1963) refers to actors in the real estate market who maintain that keeping housing vacant not is particularly advantageous for the owners. This is also an argument for maintaining that vacancies are kept at a low level. However, vacancies are varying, and Maisel found that vacancies are important. He refers that many experts argue that a “normal” vacancy is at a level of 5 per cent. However, Maisel indicates that vacancies were observed to have a significant effect on starts; “The level of vacancies appears to play a role in each cycle. ----- vacancies appear to have had far more influence on starts than most observers noted. -----In addition to changes in vacancies, fluctuations in inventories under construction are extremely important.” By testing relations in his model, Maisel found that changes in inventories accounted for 85 per cent of the variance in starts, “while the complementary movements in basic demand were related to less than 15 per cent”. Vacancies are not explicitly modelled in this “Norwegian” housing model, it appears at best as the discrepancy between the housing stock and housing demand. Future refinements on a similar system dynamics model may therefore, in line with what Maisel maintains, explicitly include vacancies.

Speculation in the housing market has increasingly been observed during the long period of rising house prices. Investors are buying primarily from new housing projects in the advance sales process, having to pay only a ten per cent of the required price in advance. When a market downturn is expected (which currently seems to occur at the moment), the speculants try to sell off in order to gain some of the expected profits, or in order to minimise losses. Depending on the extent of such purchases, it will be interesting to enhance a model to include this as well because these actors’ influence may boost both planning and construction starts and therefore also vacancies.

11.2 BUDGET CONTROL

The budget share of housing is according to Statistics Norway at a level of 22 per cent. Obviously, the budget share will not vary extremely much despite the fact that the level has varied, among other things because of varying interest rates. The current model has no built-in budget control. The model may be enhanced by using for instance a two-commodity model; housing and “other goods and services”. The knowledge about direct price elasticities and cross elasticities as well as feasible budget shares could be employed in order to achieve a more realistic model. Furthermore, using expenditures as argument instead of housing prices is more realistic. Loan repayments and interest rates will be part of the housing expenditures that also include stable elements such as the much less variable maintenance costs, fuel and. The reason why the “housing price elasticity” has such a low value as indicated above may be founded on the fact that the estimates are based just on one of the indicators, housing price, not all components that constitute housing expenditures. Interests and repayments are probably better explanation variables than price only. Expenditures may in practice for instance change for a longer repayment time; such adjustments are recently observed, and this is a resulting adjustment people try to achieve in order to compensate for recent housing price increases.

11.3 THE RENTAL MARKET

During the current work much of the discussion seems to reflect owner-occupied housing. Even though 80 per cent of the Norwegian homes are owner-occupied, there are a considerable number of tenants who are renting their dwellings. Apartments for tenants are not so much in blocks of flats that are more commonly seen other places in Europe. 10 per cent of the households own an additional dwelling; either used by the household itself, rented out, or is unoccupied. Such additional dwellings represent the largest amount of housing for rental (KRD (2002)).

The rental market has increasingly become a market for short term contracts. Demand for such housing has increased much, which also is reflected in price increases in the rental market; however, the price development has not necessarily changed equally in the owner-

occupied housing market compared to the rental market. In order to fully reflect how the housing market behaves, efforts to model such a two-part market might be fruitful in the sense that this better reflects realities. Such a model may possibly also reveal interesting behaviour.

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APPENDIX 1: OUTLINE OF A DEMAND FUNCTION

The demand function

In the modelling in the current thesis, a “traditional” aggregate economic demand function is employed. In this context, aggregate demand is the total demand from the individual consumers, or households, in the economy. Elasticities are fundamental in such theory, and, for instance price elasticity expresses, though not mathematically precise, “the percent change in demand of a good when the price increases by one percent”. For instance, if demand declines 0.3 percent when the price increases one percent, the price elasticity equals $-0.3/1 = -0.3$. Equally the income elasticity is the per cent change in demand for a one per cent change in income.

The reason for using demand elasticities in the modelling is that the concept is well-known and basic in economic theory, and, estimates indicate a range of values they can (and cannot) take. When estimates are lacking, this knowledge is invaluable for modelling demand. The “average” direct price elasticity of consumer goods should equal -1, in the sense that if prices of all goods and services increase by one percent, the total consumer demand for goods will correspondingly be reduced by one percent, approximately. Necessities, such as standard food and housing, are usually inelastic with respect to price, i.e., with values ranging between -1 to zero. Depending on the character of the goods in question, for instance in the case of standard food vs. luxury food, smaller houses vs. larger houses. The direct price elasticity of “luxury” goods is in general assumed to have a higher absolute value than necessities. In average, the income elasticity will have an average value in the sense that when disposable income increases by one percent, the general consumption of goods including services will increase by one percent, savings not considered. As disposable income increases, the propensity to increase demand for a given good will eventually decrease, i.e., there are limits for how much a consumer will consume of that particular good.

In general, we may assume that a goods price elasticity’s absolute value will decline to zero as the price of the good declines to zero. As income increases the income elasticity will decline for a given good.

In standard textbook consumer theory the demand, in terms of quantity, for an economic good depends on the price of the good itself, prices of other goods, and disposable income - quantity=f(prices, income). Differentiation and rearrangement of this expression gives the following equation:

$$\frac{\partial q_i}{\partial p_i} = e_{ii} \frac{\partial p_i}{\partial p_i} + \sum_{j=1}^n e_{ij} \left(\frac{\partial p_j}{\partial p_i} \right) + E_i \left(\frac{\partial r}{\partial p_i} \right) \quad \text{where}$$

$$i \neq j, (i, j) \in N = \{1, 2, \dots, n\} \quad \text{and}$$

$q_{i,j}$ = total demand for good i, j

$p_{i,j}$ = price for good i, j

r = disposable income

$e_{ii} = \frac{\partial q_i}{\partial p_i} / \frac{\partial p_i}{\partial p_i}$ - the direct price elasticity, price elasticity of good i with respect to a

change in the good's price

$e_{ij} = \frac{\partial q_i}{\partial p_j} / \frac{\partial p_j}{\partial p_j}$ cross price elasticity, price elasticity of good i with respect to a change in

price of good j

$E_i = \frac{\partial q_i}{\partial r} / \frac{\partial r}{\partial r}$, income elasticity, elasticity of good i with respect to a change disposable

income

N = the entire set of consumer goods and services available - $\{1, 2, \dots, n\}$

Even for a to-commodity approach with housing and “other goods and services” in order to keep track on other goods, direct price elasticities, cross price elasticities and the limitations for housing expenditures, a stock-flow representation would be rather complicated in terms of “traditional” consumer demand theory.

To simplify for modelling purposes, the approach above can be reduced to include solely housing – a one-commodity demand function derived from the general, so-called Marshallian demand function. For housing alone, according to the general equation xx above, the change in demand can be expressed in the following way:

$$\frac{\partial q}{\partial p} = e \frac{\partial p}{\partial p} + E \left(\frac{\partial r}{\partial p} \right)$$

in which $\frac{\partial q}{q}$ is the relative (“percentage”) change in demand for housing, $\frac{\partial p}{p}$ the relative change in price of housing and $\frac{\partial r}{r}$ the relative change in disposable income. The price elasticity e and the income elasticity E can be used as explicit changeable parameters in a model, either as changeable constants or variables. The corresponding entities for q , p and r in the dynamic model will be stocks, q a material stock, the other two information stocks.

Alternatively, when other goods and services are left out, a so-called Cobb-Douglas demand function performs exactly in the same manner as the function above, the one-commodity approach derived from a general demand function. There are differences between the general approach and the Cobb-Douglas function regarding discrete calculation – the general approach above implies disintegration and integration. A Cobb-Douglas demand function, in this context, implies calculations directly from changes in price, income and population relative to their initial values. Deviations between the two approaches arise from the principle of discrete approximations in computer calculations. For small time steps in the calculations, discrepancies are negligible – the two approaches produce practically the same results in a one-commodity model. The Cobb-Douglas function is as follows with the same symbol notation as above

$$q_t = q_0 \cdot \left[\frac{p_t}{p_0} \right]^e \cdot \left[\frac{r_t}{r_0} \right]^E$$

in which q_0 , p_0 and r_0 are initial values, and q_t , p_t and r_t are values at time t .

Estimates of demand elasticities

The income elasticity, with the more “practical” definition is the change in demand in per cent for a one per cent change in income (or consumption expenditures). There are few references in the literature to estimates of elasticities, however, a few exist. For Norway there is one notable effort.

In Larsen (2007), expenditure elasticity estimates (Engel elasticities) for housing are presented. Strictly defined, the Engel elasticity is the change in demand for a commodity or a service for an infinitesimal change in income. This source indicates that when consumer

expenditures or the general public income per capita level increase by one per cent, the housing expenditures increase by approx. one per cent, i.e., an elasticity around unity (given fixed prices). This analysis is based on cross-sectional data from the Norwegian Consumer Expenditure surveys, regularly carried out by Statistics Norway. For the years 1986 to 1998 the estimated Engel elasticity has varied from 0.71 to 1.29, however, with most values close to unity. The average for all years is 1.02, and this result may be interpreted that the “consumption of housing” increases, in per cent, at the same rate as income. Larsen (2007) also refers to similar findings from other sources: “.....Segal finds that, while American households devoted on average 25% of their budgets to housing in 1901, they continue to spend 27% of the budget on housing today. This remarkable stability of the budget share of housing expenditure hints at an Engel elasticity of magnitude one”. It is argued that necessities have Engel elasticities below one, i.e., as income increases; budget shares for these goods will decline; food is one example. Luxury goods’ elasticities will be above unity, which means that demand increases at a higher rate than income. Larsen (2007) points out that the budget share for transport during the last hundred years has increased from 2 to 20 per cent. Since shelter is a necessity, but, on the other hand, housing reflects social status, housing has a mixed status as a necessity on the one hand, and a luxury good on the other hand.

There are no estimates of direct housing price elasticities for Norway. However, Hanushek and Quigley (1980) indicate, based on data from Pittsburg and Phoenix that the confidence intervals for the price elasticities are -0.22 to -0.54 for Pittsburg, and -0.19 to -0.63 for Phoenix. The method is based on housing expenditures measured in current prices, not to quantities, such as area and number of housing units or housing area. The estimates therefore probably also will reflect other qualities of housing, such as standard, location etc.

Barot (2006) gives a strong support to the indications from Larsen (2007) that income elasticities for housing is at a level close to unity: “We find no compelling reason either in the Swedish or the UK literature to reject unitary income elasticity”. Regarding price elasticities, Barot (2006) refers to a number of sources in the UK and Sweden for price elasticity estimates for housing. For the UK the estimates range from -0.4 to -0.8. Estimates of the Swedish housing market range from -0.3/-0.4 in one source, and -0.5 in another source.

A note on the housing “price”

Price is one element of a bundle of components constituting housing expenditures – the price of a purchased home, loan interests and repayments, property taxes, maintenance costs, electricity etc. Housing prices and the interest rates on loans have historically probably varied much more than the other components, such as taxes and maintenance, and are therefore of special interest both for those who are selling and purchasing in the housing market.

Average housing expenditures have increased after the 1950-ies. Today, housing expenditures are somewhat less than 30 per cent of disposable income. Housing expenditures cannot exceed certain values. This limitation is not implemented in the model, but is a relevant modification for an extended model.

APPENDIX 2A: MODEL EQUATIONS AND UNITS

DEMAND

demand_supply_ratio = housing_demand/housing_stock
dimensionless

desired_housing =
 initial_desired_housing*((expected_price/initial_expected_price)^Price_elasticity)*
 (other_variables)
square_meters

housing_demand = smth1(desired_housing,delay_time,order)
square_meters

initial_desired_housing = 100
square_meters

initial_expected_price = 100
NOK/square_meter

other_variables = 1
dimensionless

delay_time = 2
year

order = 1
dimensionless

Price_elasticity = -.2
*dimensionless; (dq*p)/(dp*q) (Appendix 1)*

SUPPLY

housing_stock(t) = housing_stock(t - dt) + (completion_rate - removals) * dt
 INIT housing_stock = desired_housing
square_meters

INFLOWS:
 completion_rate = construction_capacity*constr_cap_utilisation
square_meters/year

OUTFLOWS:
 removals = housing_stock/average_lifetime

square_meters/year

$\text{under_construction}(t) = \text{under_construction}(t - dt) + (\text{construction_start_rate} - \text{completion_rate}) * dt$
square_meters/year

INIT $\text{under_construction} = \text{removals} * \text{normal_construction_time}$
square_meters

INFLOWS:

$\text{construction_start_rate} = \text{UNDER_PLANNING} / \text{normal_time_to_plan}$
square_meters/year

OUTFLOWS:

$\text{completion_rate} = \text{construction_capacity} * \text{constr_cap_utilisation}$
square_meters/year

$\text{under_planning}(t) = \text{under_planning}(t - dt) + (\text{planning_start_rate} - \text{construction_start_rate}) * dt$

INIT $\text{under_planning} = \text{planning_start_rate} * \text{normal_time_to_plan}$
square_meters

INFLOWS:

$\text{planning_start_rate} =$
 $f_desadd_to_cc_ratio * \text{construction_capacity} * \text{profit_rate_initiation_function}$
square_meters/year

OUTFLOWS:

$\text{construction_start_rate} = \text{UNDER_PLANNING} / \text{normal_time_to_plan}$
square_meters/year

$\text{average_lifetime} = 100$
years

$\text{desadditions_cc_ratio} = \text{desired_additions} / \text{construction_capacity}$
dimensionless; i.e., (square_meters/year/square_meters/year)

$\text{descap_cc_ratio} = \text{desired_capacity} / \text{construction_capacity}$
dimensionless; i.e., (square_meters/year)/(square_meters/year)

$\text{desired_additions} = \text{housing_gap} + \text{expected_removals}$
square_meters/year

$\text{desired_capacity} = \text{under_construction} / \text{normal_construction_time}$
square_meters/year

$\text{expected_profit_rate} = (\text{expected_price} - \text{expected_cost}) / \text{expected_cost}$
dimensionless; (NOK/square_meter)/(NOK/square_meter)

$\text{expected_removals} = \text{housing_stock} / \text{average_lifetime}$

square_meters/year

housing_gap = (housing_demand-housing_stock)/housing_gap_adjustment_time
square_meters/year

housing_gap_adjustment_time = 1
year

normal_construction_time = 2
year

normal_time_to_plan = 2
year

adj_for_constr_WIP = (desired_under_construction-
 under_construction)/construction_WIP_adj_time
square_meters/year

adj_for_planning_WIP = (desired_under_planning-under_planning)/planning_WIP_adj_time
square_meters/year

adjusted_desired_additions_to_constr_cap_ratio =
 des_additions_adjusted_for_WIP/construction_capacity
square_meters/year

construction_WIP_adj_time = .2
years

des_additions_adjusted_for_WIP =
 desired_additions+adj_for_constr_WIP+adj_for_planning_WIP
square_meters/year

desired_additions = housing_gap+expected_removals
square_meters/year

desired_under_construction = construction_capacity*normal_time_to_construct
square_meters

desired_under_planning = construction_capacity*normal_time_to_plan
square_meters

expected_removals = housing_stock/average_housing_lifetime
square_meters/year

housing_gap = (housing_demand-housing_stock)/housing_gap_adjustment_time
square_meters/year

housing_gap_adjustment_time = 1
years

planning_WIP_adj_time = .2
years

constr_cap_utilisation = GRAPH(descap_cc_ratio)
(0.00, 0.00), (0.2, 0.35), (0.4, 0.61), (0.6, 0.79), (0.8, 0.91), (1.00, 1.00), (1.20, 1.07), (1.40, 1.10), (1.60, 1.16), (1.80, 1.18), (2.00, 1.21)
dimensionless; descap_cc_ratio

f_desadd_to_cc_ratio = GRAPH(adjusted_desired_additions_to_constr_cap_ratio)
(0.00, 0.00), (0.2, 0.33), (0.4, 0.57), (0.6, 0.75), (0.8, 0.89), (1.00, 1.00), (1.20, 1.09), (1.40, 1.15), (1.60, 1.21), (1.80, 1.24), (2.00, 1.27)
dimensionless; desadditions_cc_ratio

profit_rate_initiation_function = GRAPH(expected_profit_rate)
(-0.2, 0.1), (-0.15, 0.26), (-0.1, 0.51), (-0.05, 0.74), (-4.16e-017, 1.00), (0.05, 1.25), (0.1, 1.70), (0.15, 2.10), (0.2, 2.60), (0.25, 3.30), (0.3, 3.60), (0.35, 3.90), (0.4, 3.90), (0.45, 4.00), (0.5, 4.00)
dimensionless; i.e., (expected_price - expected_cost)/expected_cost

CAPACITY

jobless(t) = jobless(t - dt) + (net_hiring - jobless_attrition_rate) * dt
INIT jobless = 0
workers

INFLOWS:
net_hiring = max(0, -labour_gap/firing_adjustment_time) -
max(0, labour_gap/effect_of_unemployment_on_net_hiring)
workers/year

OUTFLOWS:
jobless_attrition_rate = jobless/jobless_attrition_time
workers/year

labour(t) = labour(t - dt) + (recruitment_completion_rate - labour_attrition_rate - net_hiring) * dt
INIT labour = desired_labour
workers

INFLOWS:
recruitment_completion_rate = recruits/training_time
workers/year

OUTFLOWS:
labour_attrition_rate = labour/labour_attrition_time
workers/year

net_hiring = max(0, -labour_gap/firing_adjustment_time) -
 max(0, labour_gap/effect_of_unemployment_on_net_hiring)
workers/year

recruits(t) = recruits(t - dt) + (recruitment_startrate - recruitment_completion_rate) * dt
 INIT recruits = recruitment_startrate*training_time
workers

INFLOWS:

recruitment_startrate = max(0, labour_gap/time_to_recruit+expected_labour_quit_rate)
workers/year

OUTFLOWS:

recruitment_completion_rate = recruits/training_time
workers/year

construction_capacity = labour*productivity
*square meters/year; i.e., workers*square meters/year/worker*

desired_labour = desired_capacity/productivity
workers/year; i.e., (square meters/year) / [(square meters/year) /worker]

expected_labour_quit_rate = labour/labour_attrition_time
workers/year

firing_adjustment_time = 1
years

jobless_attrition_time = 5
years

labour_attrition_time = 10
years

labour_gap = desired_labour-labour
workers

productivity = 2
(square meters / year) /workers

time_to_recruit = 1
years

training_time = 3
years

unemployment_rate = jobless/(labour+jobless)
dimensionless; i.e., workers/workers

time to employ jobless = GRAPH(unemployment_rate)
 (0.00, 100000), (0.01, 6.00), (0.02, 3.20), (0.03, 1.75), (0.04, 1.15), (0.05, 0.65), (0.06, 0.45),
 (0.07, 0.35), (0.08, 0.2), (0.09, 0.1), (0.1, 0.1)

years; a given dimension to the dimensionless time_to_employ_jobless. Alternatively time_to_employ_jobless that strictly spoken is dimensionless (from unemployment_rate that is defined as workers/workers), in combination with a constant “normal time to employ jobless”, would give dimension years

COSTS

expected_cost(t) = expected_cost(t - dt) + (expected_cost_change_rate) * dt
 INIT expected_cost = 100
costs/square meter

INFLOWS:

expected_cost_change_rate = (indicated_cost-expected_cost)*1/cost_expectations_adj_time
(costs/square meter)/year

cost = effects_on_cost*expected_cost
costs/square meter

cost_expectations_adj_time = 2
years

cost_minimum = 100
costs/square meter

indicated_cost = max(cost_minimum,cost)
 effects_on_cost = GRAPH(desired_capacity/construction_capacity)
 (0.00, 0.874), (0.2, 0.874), (0.4, 0.886), (0.6, 0.91), (0.8, 0.952), (1.00, 1.00), (1.20, 1.08),
 (1.40, 1.14), (1.60, 1.20), (1.80, 1.23), (2.00, 1.23)
costs/square meter

PRICES

expected_price_EP(t) = Expected_price_EP(t - dt) + (d_EP) * dt
 INIT expected_price = 100
price/square meter

INFLOWS:

expected_price_change_rate = (price-expected_price)/expected_price_adj_time
price/square meter/year

price = effect_of_demand_supply_ratio*expected_price
price/square meter

expected_price_adj_time = 1
year

effect_of_demand_supply_ratio = GRAPH(demand_supply_ratio)
 (0.00, 0.00), (1.00, 1.00), (2.00, 2.00)
dimensionless; demand/supply, (square meters)/(square meters)

DEMAND

demand_supply_ratio = housing_demand/housing_stock
dimensionless; demand/supply, (square meters)/(square meters)

desired_housing = initial_desired_housing*((expected_price
 /initial_expected_price)^Price_elasticity)*(other_variables)
*square meters; i.e., initial_desired_housing (square meters) multiplied with dimensionless
 variables*

housing_demand = smth1(desired_housing,2)
square meters

initial_desired_housing = 100
square meters

initial_expected_price = 100
price; e.g., NOK

other_variables = 1
dimensionless

Price_elasticity = -0.4
*dimensionless; i.e., (quantity*price)/(quantity*price)*

APPENDIX 2B: EXOGENOUS INPUT AND ADJUSTED PARAMETERS

The “*other_variables*” defined as the following:

other_variables=[(consumption/initial_consumption)^income_elasticity]*[population/initial_
 population]*[effect_of_ir]

firing_adjustment_time = 1

jobless_attrition_time = 5

labour_attrition_time = 10

time_to_recruit = 1

training_time = 3

price_elasticity = -0.26

income_elasticity = 1

consumption_fract_change_rate = GRAPH(TIME) (consumption divided by consumption in the preceding year minus one)

(1950, 0.012), (1951, -0.00783), (1952, 0.0302), (1953, 0.0297), (1954, 0.0201), (1955, 0.0208), (1956, 0.0194), (1957, 0.014), (1958, -0.00564), (1959, 0.0323), (1960, 0.0729), (1961, 0.0501), (1962, 0.0221), (1963, 0.0262), (1964, 0.0297), (1965, 0.0165), (1966, 0.0279), (1967, 0.0302), (1968, 0.0276), (1969, 0.068), (1970, -0.00803), (1971, 0.049), (1972, 0.0197), (1973, 0.0274), (1974, 0.0232), (1975, 0.0481), (1976, 0.0547), (1977, 0.0583), (1978, -0.0205), (1979, 0.0382), (1980, 0.0168), (1981, -0.00191), (1982, 0.00687), (1983, 0.0147), (1984, 0.0287), (1985, 0.0905), (1986, 0.0463), (1987, -0.012), (1988, -0.0256), (1989, -0.0115), (1990, 0.00416), (1991, 0.0186), (1992, 0.0158), (1993, 0.018), (1994, 0.027), (1995, 0.0311), (1996, 0.0597), (1997, 0.027), (1998, 0.0207), (1999, 0.0261), (2000, 0.0317), (2001, 0.0122), (2002, 0.0255), (2003, 0.023), (2004, 0.0413), (2005, 0.0315)

POPULATION SECTOR

POP(t) = POP(t - dt) + (DPOP) * dt

INIT POP = 100

INFLOWS:

DPOP = EXOG_CH_POP*POP

EXOG_CH_POP = GRAPH(TIME) (population divided by population in the preceding year minus one)

(1950, 0.00977), (1951, 0.00934), (1952, 0.0095), (1953, 0.00983), (1954, 0.0101), (1955, 0.00976), (1956, 0.0102), (1957, 0.00877), (1958, 0.00923), (1959, 0.00856), (1960, 0.0084), (1961, 0.00759), (1962, 0.00836), (1963, 0.00777), (1964, 0.00741), (1965, 0.00776), (1966, 0.00785), (1967, 0.00818), (1968, 0.00862), (1969, 0.00826), (1970, 0.0081), (1971, 0.00649), (1972, 0.00758), (1973, 0.00778), (1974, 0.00627), (1975, 0.00618), (1976, 0.0049), (1977, 0.00451), (1978, 0.00397), (1979, 0.00368), (1980, 0.00314), (1981, 0.0033), (1982, 0.0036), (1983, 0.00376), (1984, 0.00287), (1985, 0.00278), (1986, 0.00322), (1987, 0.00393), (1988, 0.00545), (1989, 0.00533), (1990, 0.00295), (1991, 0.00395), (1992, 0.0056), (1993, 0.00597), (1994, 0.00597), (1995, 0.00546), (1996, 0.00496), (1997, 0.00521), (1998, 0.00567), (1999, 0.00628), (2000, 0.00746), (2001, 0.00557), (2002, 0.00458), (2003, 0.00623), (2004, 0.00554), (2005, 0.00631)

effect_of_demand_supply_on_price = demand_supply_ratio

expected_price_adj_time = 0.5

average_housing_lifetime = 150

expected_cost_adj_time = 2

historical_real_price_index = historical_prices*3.5

housing_gap_adjustment_time = 1

normal_time_to_construct = 1

normal_time_to_plan = 1

effects_on_cost = GRAPH(desired_cap_to_capacity_ratio)

(0.00, 0.908), (0.2, 0.917), (0.4, 0.929), (0.6, 0.941), (0.8, 0.965), (1.00, 1.00), (1.20, 1.04), (1.40, 1.06), (1.60, 1.07), (1.80, 1.09), (2.00, 1.10)

f_desadd_to_cc_ratio = GRAPH(adjusted_desired_additions_to_constr_cap_ratio)
 (0.00, 0.00), (0.2, 0.33), (0.4, 0.57), (0.6, 0.75), (0.8, 0.89), (1.00, 1.00), (1.20, 1.09), (1.40, 1.15), (1.60, 1.21),
 (1.80, 1.24), (2.00, 1.27)

historical_interest_rates = GRAPH(TIME)
 (1950, 0.02), (1951, 0.02), (1952, 0.02), (1953, 0.02), (1954, -0.01), (1955, 0.013), (1956, -0.011), (1957, -0.002), (1958, -0.02), (1959, 0.002), (1960, 0.028), (1961, 0.004), (1962, -0.025), (1963, 0.005), (1964, -0.024), (1965, -0.01), (1966, 0.003), (1967, -0.0119), (1968, -4.61e-006), (1969, 0.00826), (1970, -0.0639), (1971, -0.0207), (1972, -0.0316), (1973, -0.034), (1974, -0.0508), (1975, -0.0699), (1976, -0.0436), (1977, -0.0424), (1978, -0.0246), (1979, 0.0119), (1980, -0.0511), (1981, -0.0677), (1982, -0.0399), (1983, -0.0081), (1984, 0.00948), (1985, 0.0153), (1986, 0.0106), (1987, 0.0112), (1988, 0.0327), (1989, 0.0438), (1990, 0.0457), (1991, 0.053), (1992, 0.0729), (1993, 0.0535), (1994, 0.0449), (1995, 0.0306), (1996, 0.038), (1997, 0.0167), (1998, 0.0339), (1999, 0.0351), (2000, 0.038), (2001, 0.037), (2002, 0.054), (2003, 0.002), (2004, 0.016), (2005, 0.004)

effect_of_ir = GRAPH(historical_interest_rates)
 (-5.00, 1.10), (-3.00, 1.08), (-1.00, 1.06), (1.00, 1.04), (3.00, 1.00), (5.00, 0.962), (7.00, 0.938), (9.00, 0.906),
 (11.0, 0.896), (13.0, 0.882), (15.0, 0.862)

historical_prices = GRAPH(TIME)
 (1980, 100), (1981, 101), (1982, 93.1), (1983, 85.1), (1984, 94.1), (1985, 104), (1986, 107), (1987, 104), (1988, 93.1), (1989, 83.2), (1990, 75.2), (1991, 70.3), (1992, 69.3), (1993, 77.2), (1994, 81.2), (1995, 87.1), (1996, 94.1), (1997, 101), (1998, 108), (1999, 117), (2000, 132), (2001, 137), (2002, 142), (2003, 141), (2004, 154), (2005, 164)

APPENDIX 3: SEMI-STRUCTURED INTERVIEWS WITH REAL ESTATE DEVELOPERS

Interview guide; housing construction

A

What is the basis for starting housing construction? Expected

-expected price, expected costs?

-advance sales?

-financing?

B

Do you use forecasts for

-housing prices

-construction costs

-formalised cost-benefit analyses

C

What kind of information in addition to prices and construction costs are used in decisions concerning decisions on housing construction?

D

Are there variations for the construction over time?
If variations – what are the most important causes?

E

What is the normal time from

-a decision about housing construction ahead of an application for a General permit is submitted to the authorities?

a) for detached and/or small housing

b) for large multi-dwelling housing

-a General permit is given to construction starts?

a) for detached and/or small housing

b) for large multi-dwelling housing

F

By low construction activity over a long time – will construction workers be
dismissed
given notice - fired
moved to other kinds of construction and building?

G

When construction activity is high – please describe how recruitment of construction workers is carried out.

Is it favourable to use Norwegian/Nordic construction workers?

How long time does it take to build efficient worker groups?

H

Defects in the construction process – is this dependent on qualifications?

Does it happen that planned construction projects are cancelled?

If projects are cancelled – what are the most common causes?

Two interviews were accomplished, one with a commercial real estate developer and one with a housing co-operative institutions. A merged summary of the main findings are presented in the following:

A

We are talking about before and after 1988. The municipality had early established a company for preparing ground for construction (GC). Before 1998 the co-operative building societies (BBLs) had priority to private real estate developers when ground should be assigned for housing construction. The demand for housing was permanently high, and planning and construction could be implemented cautiously. After 1988 the BBLs got problems when prices and demand declined. After 1991 it was again possible for the BBLs to go into construction with profitability. However, the GC turned its strategy to sell to the highest bidder – full competition was introduced. For new projects, the BBL now considers the ground according to location and facilities in the neighbourhood. Commercial considerations take place.

Prices for ground are important. Available infrastructure, such as roads, kindergartens, schools, cleaning plants is considered. In case of greenfield/brownfield, the costs of

infrastructure development have to be considered. Today the authorities often require real estate developers to contribute to the financing of infrastructure.

If construction is decided upon, purchase of separate contracting from 16-17 sub-contractors take place. This has turned out to be less costly than using a single main-contractor, resulting in lower prices for the final housing.

The sales office is actively utilised for acquiring information about trends regarding saleability for housing of different kinds and with different types of facilities. Judgement is important, not necessarily formal cost benefit calculations. Judgements of market prices and a consideration about a reasonable markup is the basis for housing construction.

Advance sales are a prerequisite for construction. 40 per cent of the *value* of a project has to be booked in advance, the remaining 60 percent is guaranteed for insurance in the BBLs umbrella organisation, NBBL. Before construction housing is always partly sold in advance. In case of financing through private financial institutions, 60 per cent advance sales are required.

The respondent that represented the private real estate developer informed that 60 per cent advance sales are required, and the buyers had to pay 10 per cent of the value when contracts were signed. Construction loans were financed by private institution, not the State Housing Bank today.

B

Co-operatives' respondent: Forecasts are permanent preconditions for project evaluation. Both housing price forecasts and construction cost forecasts are used actively. One particular problem is that the authorities increase the burden on the real estate developers. When the pressure is high, subcontractors raise their product prices, when pressure is low they are letting prices down.

Private developer: No formal forecasts, however, statistics are used actively, both its own statistics and statistics bought from consultancy companies. Advanced spreadsheet calculations were employed, and in-house specialists consulted.

C

Check-lists are used prior to purchasing ground. Price, pollution, noise, centrality, need for building infrastructure, status of regulations, etc., are important input.

D and E

Co-operatives' respondent: Time to construct varies, but not very much. Need for draining of the raw building constructions contributes to extend the construction time.

Private developer: Provided that the building site is completely regulated, about 6 months. For unregulated sites at least one additional year. 6-8 months from a given General Permit until construction start. Construction starts after permission for this takes "some weeks"

In many cases, unregulated areas are considered related to attractiveness and facilities, potential customers, etc. In total, 5-6 years is required in such cases, and 3-4 years of regulation from the hands of the authorities is required.

For completely regulated areas it will take 3-6 months from decision of planning for construction takes place until a general permit is submitted, sometimes up to 9 months, depending on whether we talk about greenfield/brownfield land versus existing housing areas. In existing housing area the process tends to take longer time than 3-6 months.

From a general permit is given, it takes 1-2 months from a general permit before construction start takes place.

When the authorities are overloaded with work, they are using longer time, even if they loose fees. Even when complete applications are submitted, it occurs that the authorities require additional information and documents in order to win more time. In normal times the authorities' time for approval is a certain number of weeks.

F

Unskilled workers are going first when construction activities decline. Skilled labour is kept as long as possible, among other things by employment in other activities even when these activities contribute to deficits. Contractors "purchase" projects in order to keep valuable competence. Attrition time for skilled labour was estimated to approx. 20 years, while, on the other hand, jobless unskilled workers' attrition time could be much lower, perhaps 5 years.

G

When activity is high, apprentices are recruited. In the 1980-ies, people from Finland, Denmark and Sweden were hired. Today Polish workers are hired to a great extent and work quality is good, however, this requires extra management control compared to using Norwegian workers. Knowledge of construction traditions and the ease of using the same native language counts.

Tariff wages are used, and Scandinavian workers are preferred.

H

Co-operatives' spokesman: Defects in the construction process and rework is affected by qualifications. Plans are sometimes postponed in order to see whether the market situation improve. Sometimes total replanning is required. This occurs now, but since 1988-1991 there has been almost a continuing growth in the demand, so, re-planning has nearly not taken place after 1991.

Private developer's spokesman: Control functions are employed in the construction process in order to detect defects. However, labour qualifications are important. Sometimes projects are abandoned, either totally, or postponed. Perhaps one of ten projects are abandoned, and the reasons vary, one reason is when construction costs appear to be too high, changes in market conditions and misjudgements regarding the building site.